

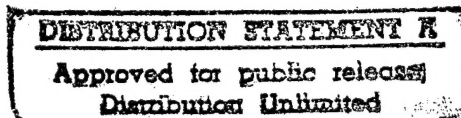


**U.S. Army
Environmental
Center**

**FORT DEVENS
FEASIBILITY STUDY
FOR GROUPS 2 & 7 SITES**

**FINAL
FEASIBILITY STUDY REPORT
AREA OF CONTAMINATION (AOC) 43J**

**CONTRACT DAAA15-91-D-0008
DELIVERY ORDER NUMBER 005**



**U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND**

June 1996

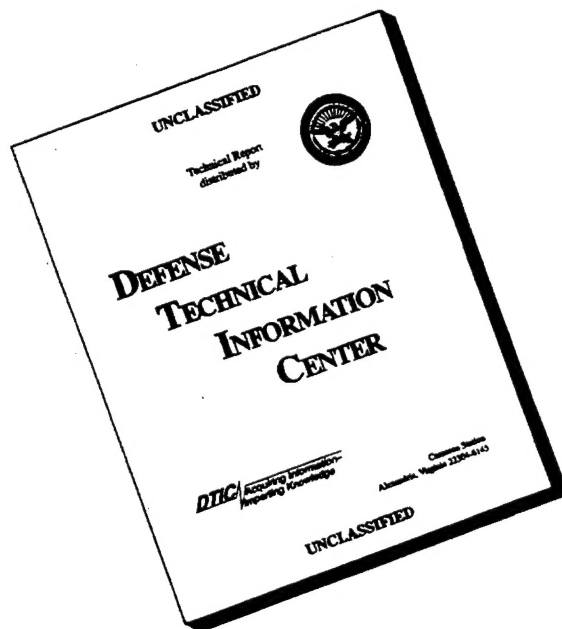
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FORT DEVENS FEASIBILITY STUDY FOR GROUP 2 & 7 SITES

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DELIVERY ORDER NUMBER 005

Prepared for:

U.S. Army Environmental Center
Aberdeen Proving Ground, Maryland

Prepared by:

ABB Environmental Services, Inc.
Wakefield, Massachusetts
Project No. 07053-11

JUNE 1996

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EXECUTIVE SUMMARY

The U.S. Army Environmental Center directed ABB Environmental Services, Inc. (ABB-ES), under Contract No. DAAA15-91-D-0008, to conduct a Remedial Investigation (RI) and Feasibility Study (FS) to address the contamination of soil and groundwater at Area of Contamination (AOC) 43J at Fort Devens, Massachusetts. This FS Report is prepared as part of the FS process in accordance with the 1988 U.S. Environmental Protection Agency (USEPA) guidance document entitled *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. The purpose of the FS Report is to initially identify and screen potentially feasible alternatives to control human health and environmental risks at AOC 43J. Following this screening, the FS Report presents a detailed analysis and comparative analysis of the retained alternatives.

AOC 43J is situated on an access road that connects Patton Road with Queenstown Road in the central portion of the Main Post. The area around the location of AOC 43J is presently unoccupied but was most recently a vehicle storage yard and maintenance facility (Building T-2446) for a Special Forces Unit of the U.S. Army. The yard and maintenance facility is paved with asphalt and surrounded by a chain-link fence with a locked gate located at the northern side of the yard. Prior to the construction of the Special Forces Unit vehicle maintenance facility, this area was used historically as a gas station/motor pool during World War II. The motor pool operations were discontinued during the late 1940s or early 1950s. The structure of this historic gas station at AOC 43J consisted of a pump island and a small gasoline pumphouse.

A 5,000-gallon underground storage tank (UST) was removed from this area in August 1992. However, an Underwriters Laboratory tag found on the UST indicated that this UST was of a younger age than the reported age of the historic gas station at AOC 43J. In May 1992, the Army also removed a 1,000-gallon waste oil UST approximately 50 feet east of the historic gas station UST. This UST was used by the Special Forces unit for the storage of waste oil generated from the maintenance operation at this facility. Petroleum contaminated soils around both of these USTs were removed when the USTs were excavated. Field investigations revealed that the original 5,000-gallon UST (or replacement UST) and the 1,000-gallon waste oil UST were sources of groundwater contamination at AOC 43J.

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The RI Report evaluated potential human health risks associated with exposure to site contaminants in subsurface soil and groundwater based on soil and groundwater sampling data collected during the RI (ABB-ES 1996). The risk assessment was conducted to evaluate potential human health risks to commercial/industrial receptors under current and future foreseeable site conditions. Commercial/industrial receptors were selected because the property at AOC 43J is to be retained by the Army. Future use of the site is to be similar to current use (commercial/industrial). According to the Devens Reuse Plan (Vanasse Hangen Brustlin, 1994), the area downgradient of the site (across Patton Road) will be retained by the federal government for use as the Federal Bureau of Prisons Medical Center. The cemetery, which is comprised of an approximate 450-by-350-foot parcel of land immediately across Patton Road will be retained as Army Reserve Enclave property. Therefore, drinking water supplies for residential recipients would not be expected within these immediate downgradient areas.

Human health risks exceeded the USEPA points of departure (i.e., risk management guidelines corresponding to cancer risks exceeding 1×10^{-6} and noncancer hazard index values exceeding 1) only for the risk scenario of commercial/industrial worker exposure to groundwater as a drinking water source under future land-use conditions. Based on the results of the risk assessments, the following remedial action objectives were developed in the FS Report for AOC 43J:

- Protect potential commercial/industrial receptors located on Army Reserve Enclave property from exposure to groundwater having chemicals in excess of the following Preliminary Remediation Goals (PRGs): arsenic (50 micrograms per liter [$\mu\text{g/L}$]), iron (9,100 $\mu\text{g/L}$), manganese (291 $\mu\text{g/L}$), benzene (5 $\mu\text{g/L}$), ethylbenzene (700 $\mu\text{g/L}$), toluene (1,000 $\mu\text{g/L}$), and carbon tetrachloride (5 $\mu\text{g/L}$).
- Protect potential commercial/industrial receptors located off Army Reserve Enclave property from exposure to groundwater having chemicals in excess of the above PRGs.
- Minimize the possibility of contaminated soils contributing to groundwater contamination in excess of the above PRGs.

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Based on sampling data from the RI Report (ABB-ES, 1996), the likely sources of the organic chemicals of potential concern (CPCs) are the former gasoline and waste oil USTs. Groundwater sampling also indicates that the inorganic CPCs are not from site releases but likely because of the increased solubility of these naturally occurring analytes as a result of microbial-induced oxidation-reduction processes. Upon reduction of organic compound concentrations, the inorganic CPCs are anticipated to revert back to more insoluble forms. RI data analysis also reveals that soil contaminant concentrations downgradient of the USTs are more reflective of the groundwater plume than of a smear zone or source. Soil concentrations were found to be in general equilibrium with groundwater concentrations. The implications are that soil removal would provide little benefit in remediating groundwater. Additionally, RI data indicates that no overtly contaminated soil remains around the former USTs.

This FS Report identifies and screens response actions and potential remedial technologies that are capable of attaining the remedial action objectives. Remedial alternatives were assembled using these identified remedial technologies. The alternatives were then screened based on the criteria of effectiveness, implementability and cost. All the alternatives assembled were retained for detailed analysis in the FS Report. Alternatives that undergo detailed analysis are:

Alternative 1: No Action

Alternative 2: Intrinsic Bioremediation

- intrinsic biodegradation
- predesign data collection and modeling
- installing additional groundwater monitoring wells
- long-term groundwater monitoring
- five-year site reviews

Alternative 2 would allow the natural biological degradation (intrinsic bioremediation) of the organic CPCs to continue to occur at the site without interruption. Additional groundwater data would be collected and modeling would be performed to refine degradation rates and a long-term monitoring plan. Additional monitoring wells would be installed to assess the progress of intrinsic bioremediation. A long-term groundwater monitoring plan would be implemented

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and performed on a scheduled basis. For cost estimating purposes, it is assumed that monitoring for organic and filtered inorganic CPCs plus numerous biodegradation water quality indicators would be performed on an annual basis. Five-year site reviews would be performed to assess whether the implemented remedy continues to be protective of human health and the environment. Criteria would be established to assess the progress and effectiveness of intrinsic bioremediation. The Army would implement a contingency alternative should Alternative 2 not meet the remedial objectives.

Estimated costs to implement Alternative 2 are:

\$47,200 Capital

\$394,500 Operation and Maintenance (O&M) Present Worth (PW)

\$441,700 Total PW (27 years treatment/29 years monitoring)

Alternative 3: Intrinsic Bioremediation / Passive In-Situ Bioremedial Containment

- intrinsic biodegradation (See Alternative 2)
- installing passive bioremediation wells
- passive bioremediation system maintenance
- predesign data collection and modeling (See Alternative 2)
- installing groundwater monitoring wells (See Alternative 2)
- long-term groundwater monitoring (See Alternative 2)
- five-year site reviews (See Alternative 2)

Alternative 3 implements several of the same components described in Alternative 2 (as indicated) as well as placing of a passive in-situ bioremedial system to deliver oxygen (slow release peroxide) to the downgradient edge of the contaminant plume. This system would enhance aerobic biodegradation of organics at the plume edge thereby minimizing migration of contaminants off the Army Reserve Enclave property. As with Alternative 2, the Army would implement a contingency alternative should Alternative 2 not meet the remedial objectives.

Estimated costs to implement Alternative 3 are:

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\$134,600 Capital

\$1,003,400 O&M PW

\$1,138,000 Total PW (27 years treatment / 29 years monitoring)

Alternative 4: Intrinsic Bioremediation / Hydraulic Containment

- intrinsic biodegradation (See Alternative 2)
- predesign data collection and design
- groundwater treatment facility construction
- groundwater treatment facility operation and maintenance
- installing groundwater monitoring wells (See Alternative 2)
- long-term groundwater and soil monitoring
- five-year site reviews (See Alternative 2)

Alternative 4 implements several of the same components described in Alternative 2 (as indicated) as well as installing a groundwater extraction and treat system. The objective of groundwater extraction is to halt the migration of the contaminant plume (hydraulic containment). Extraction wells would be positioned within the most contaminated portion of the plume to maximize treatment efficiency.

Because of partitioning between soil and groundwater, residual contamination will be left on the soil above the water table when the groundwater in the plume area is lowered from groundwater extraction. This residual soil contamination is to be addressed by intrinsic bioremediation in Alternative 4. If the contamination in the vadose zone soil is not reduced, the potential for groundwater re-contamination exists when the aquifer rebounds after groundwater extraction is stopped. The length of time required to reduce contaminants (through intrinsic bioremediation) within soil to concentrations that would not re-contaminate the groundwater above PRGs is estimated to be approximately 36 years.

Other components include collecting predesign data and hydrogeologic modeling to determine the number and placement of extraction wells to contain the plume, long-term monitoring of filtered inorganic and organic CPCs, and soil monitoring for CPCs.

Estimated costs to implement Alternative 4 are:

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\$270,100 Capital
\$1,433,700 O&M PW
\$1,703,800 Total PW (36 years operation / 27 years groundwater treatment /
monitoring 38 years)

Alternative 5: Groundwater Treatment / Soil Treatment

- predesign data collection and design
- Soil Vapor Extraction (SVE) system installation
- groundwater treatment facility construction (See Alternative 4)
- installing groundwater monitoring wells (See Alternative 2)
- groundwater treatment facility O&M (See Alternative 4)
- soil monitoring (See Alternative 4)
- long-term groundwater monitoring (See Alternative 4)
- five-year site reviews (See Alternative 2)
- intrinsic biodegradation (See Alternative 2)

Alternative 5 implements several of the same components described in Alternatives 2 and 4 (as indicated) and involves placement of vertical soil vent wells for SVE, and installation of aboveground soil gas treatment equipment. The objectives of groundwater extraction and treatment are a) to minimize the migration of the contamination plume (hydraulic control) and b) to remediate the aquifer. The objective of soil venting is to remediate soil directly above the groundwater table to prevent re-contamination upon aquifer rebound when groundwater extraction is stopped. Other components include pilot testing to collect SVE system design data and hydrogeologic modeling.

Estimated costs to implement Alternative 5 are:

\$388,000 Capital
\$1,489,900 O&M PW
\$1,877,900 Total PW (27 years treatment / 29 years monitoring)

The detailed analysis evaluates these five remedial alternatives with respect to the seven evaluation criteria defined by CERCLA. The evaluation criteria are divided into three specific categories during remedy selection: Threshold Criteria, Primary Balancing Criteria, and Modifying Criteria. Threshold criteria include

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Overall Protection of Human Health and the Environment, and Compliance with applicable or relevant and appropriate requirements (ARARs). Alternatives must meet threshold criteria to be chosen as the selected remedy. Primary balancing criteria include: Long-term Effectiveness and Permanence; Reduction of Toxicity, Mobility, and Volume through Treatment; Short-term Effectiveness; Implementability; and Cost. Following the detailed analysis, a comparison of the five remedial alternatives that were the focus of the detailed evaluation is performed, highlighting the relative advantages and disadvantages of the alternatives with respect to the seven evaluation criteria. The evaluation is performed to assist decision-makers in selecting a remedy that cost-effectively meets the remedial action objectives. The summary of the detailed analysis and comparative analysis follows.

Alternative 1 is considered equal to Alternative 2 considering threshold criteria except that compliance would not be able to be monitored. Alternative 1 is also considered equal to Alternative 2 considering primary balancing criteria except that there would be no risks to site-workers during remedial implementation or cost associated with implementation of Alternative 1. (There is no active remedial action or monitoring implemented in Alternative 1).

Alternative 2 is considered equal to Alternatives 3, 4 and 5 considering threshold criteria in that they all are protective of human health and meet ARARs. Alternatives 3, 4, and 5 use redundant or backup components to achieve PRGs. Alternative 2 would rely on additional data collection, modeling, long-term groundwater monitoring, five-year site reviews and contingencies for additional action to ensure that intrinsic bioremediation is protective of human health and the environment. The added treatment technologies in Alternatives 3, 4, and 5 can be interpreted as increasing the potential protectiveness for downgradient receptors, although each could also be added as contingency alternatives to Alternative 2 upon nonperformance of intrinsic biodegradation without jeopardizing overall protection of human health and the environment.

In general, Alternative 2 is also equal to or better than Alternatives 3, 4, and 5 considering primary balancing criteria. Alternatives 3, 4 and 5 more favorably offer back-up treatment processes which contribute to the reduction of toxicity, mobility and volume of contaminants, although intrinsic biodegradation is considered to be the controlling factor in determining the time required for remedial action. The back-up treatments in Alternatives 4 and 5 would generate

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concentrated waste streams (i.e., sludge, filtered material, and spent carbon) that would require disposal. Also, the potential for groundwater re-contamination exists when the groundwater table rebounds after groundwater extraction has been halted for Alternatives 4 and 5. Because of more intrusive activities, monitoring requirements and construction work, the potential for contaminant exposure and safety hazards to workers increases with Alternatives 3, 4 and 5, respectively in order presented. Alternative 2 is expected to take the same number of years for remediation as Alternatives 3 and 5 (27 years) and take a shorter time than Alternative 4 (36 years). The engineering complexity increases for each alternative (i.e., Alternative 5 > Alternative 4 > Alternative 3 > Alternative 2). Alternatives 2 through 5 all require additional data collection, modeling or pilot testing prior to design and implementation. Alternative 2 is the least expensive alternative followed by Alternatives 3, 4, and 5, in order of increasing cost.

Alternative 3 is considered equal to Alternatives 4 and 5 considering threshold criteria in that they all are protective of human health and meet ARARs. Alternatives 4 and 5 use active redundant or backup treatment components to achieve PRGs if intrinsic biodegradation does not perform as anticipated. Alternative 3 utilizes passive aerobic bioremediation to ensure protection of human health and the environment downgradient of the Army Reserve Enclave boundary. The added active treatment technologies in Alternatives 4 and 5 can be interpreted as increasing the potential protectiveness for downgradient receptors, although each could also be added as contingency alternatives to Alternative 3 upon nonperformance of intrinsic biodegradation without jeopardizing overall protection of human health and the environment. Alternative 3 is also equal to or better than Alternatives 4 and 5 considering primary balancing criteria for similar reasons specified for Alternative 2.

Alternative 4 is considered equal to Alternative 5 considering threshold criteria in that they are both protective of human health and meet ARARs. Alternatives 4 and 5 both use active redundant or backup treatment components to achieve PRGs if intrinsic biodegradation does not perform as anticipated. Alternative 5 uses an active treatment (SVE) to minimize potential groundwater re-contamination upon aquifer rebound following completion of groundwater extraction. The active treatment technology in Alternatives 5 can be interpreted as increasing the potential protectiveness for downgradient receptors. However, both alternatives require soil monitoring to assess groundwater re-contamination

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potential which could be difficult to perform because of the heterogenous soil medium and contaminant distribution.

Alternative 4 is also considered essentially equal to Alternatives 5 considering primary balancing criteria. Alternative 5 more favorably uses the back-up soil treatment process (SVE) which contributes to the reduction of toxicity, mobility and volume of contaminants within a shorter time than Alternative 4. However, additional pilot testing (SVE) is required for Alternative 5. Because of more intrusive activities, monitoring requirements and construction work, the potential for contaminant exposure and safety hazards to workers is greater for Alternative 5. Also the overall total present worth cost is greater for Alternative 5 than for Alternative 4.

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1.0 INTRODUCTION

ABB Environmental Services, Inc. (ABB-ES), has prepared this Feasibility Study (FS) Report for Area of Contamination (AOC) 43J at Fort Devens, Massachusetts in accordance with the U.S. Army Environmental Center (USAEC) Contract DAAA15-91-D-0008, Delivery Order 005.

On December 21, 1989, Fort Devens was placed on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA). In addition, under Public Law 101-510, the Defense Base Realignment and Closure (BRAC) Act of 1990, Fort Devens was selected for cessation of operations and closure. In accordance with these acts, numerous studies, including a Master Environmental Plan (Biang et al., 1992), Enhanced Preliminary Assessment, and Site Investigations (SIs) have been conducted which address potential areas of contamination referred to as Study Areas (SAs) at Fort Devens. A current total of 76 SAs have been identified and placed in 13 priority groups. These SAs are subject to a Federal Facility Agreement (FFA) (Interagency Agreement [IAG]) between the U.S. Department of the Army and the U.S. Environmental Protection Agency (USEPA) (USEPA, 1991a) for environmental investigations and remedial actions.

Beginning in 1992, SIs and Supplemental Site Investigations (SSIs) were conducted in SA Group 2. SA 43J, one of 18 historic gas stations at Fort Devens, was an SA in Group 2 that was investigated and designated as an AOC because of the presence of petroleum contamination in the soil and groundwater. The IAG under Section 120 of CERCLA requires that an FS be undertaken at an AOC to develop and analyze potential remedial alternatives leading to a Record of Decision (ROD). The USAEC directed ABB-ES to conduct a Remedial Investigation (RI) and FS to address the contamination of soil and groundwater at AOC 43J. This FS Report is prepared in accordance with USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988).

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1.1 PURPOSE AND ORGANIZATION OF REPORT

The purpose of this FS Report is to initially identify and evaluate potentially feasible alternatives to reduce potential human health risks at AOC 43J. The initial steps of this process consist of:

- establishing remedial action objectives to reduce actual or potential risks to human health or the environment at AOC 43J.
- identifying the types of response actions for soil and groundwater necessary to achieve remedial action objectives;
- identifying and screening specific remedial technologies that may be capable of attaining remedial action objectives; and
- assembling the selected representative technologies into alternatives which represent a range of treatment and containment combinations as appropriate, and screening these alternatives with respect to the criteria of effectiveness, implementability, and cost.

Following assembly and screening of the remedial alternatives, the FS report presents a detailed analysis and comparison of the retained alternatives. As part of the detailed analysis and comparison, alternatives are evaluated against seven of nine CERCLA evaluation criteria (USEPA, 1988). The seven criteria are:

1. overall protection of human health and environment;
2. compliance with applicable or relevant and appropriate requirements (ARARs);
3. long-term effectiveness and permanence;
4. reductions in toxicity, mobility, and volume through treatment;
5. short-term effectiveness;
6. implementability; and
7. cost.

The eighth and ninth CERCLA evaluation criteria-- state acceptance and community acceptance-- are modifying criteria and will be addressed following the public information meeting, public hearing, and public comment period. Figure 1-1 is a schematic of the FS process.

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The FS Report is based on information presented in the Final RI Report (ABB-ES, 1996) and the Revised Final SI Report (ABB-ES, 1995). The FS Report consists of five sections. Section 1.0 provides a brief description and history of AOC 43J. It also summarizes the nature and distribution of contamination and the human health baseline risk assessment presented in the Final RI Report (ABB-ES, 1996). Because of the nature and location of the site-related contaminants, an ecological baseline risk was not completed.

Section 2.0 identifies remedial action objectives, general response actions, and potentially applicable technologies and process options for AOC 43J. These technologies and process options are screened considering site-specific waste characteristics and applicability to the site. Section 3.0 assembles a number of potential remedial alternatives from the selected technologies and screens them based on effectiveness, implementability, and cost.

Section 4.0 provides a detailed analysis of the retained alternatives and evaluates each alternative against the seven CERCLA criteria previously listed. Section 5.0 presents a comparison of the retained alternatives that are the focus of the detailed evaluation, highlighting the relative advantages and disadvantages of the alternatives with respect to the seven evaluation criteria.

1.2 BACKGROUND

1.2.1 Site Description and History

Prior to the building of the Special Forces Unit vehicle maintenance facility, this area was used historically as a gas station/motor pool during the 1940s and 1950s. The structure of this historic gas station at AOC 43J consisted of a pump island and a small gasoline pumphouse. This gas station was reported to be a Type A station which had one 5,000-gallon (or possibly 5,140-gallon) underground storage tank (UST) located between the gasoline pumphouse and pump island. The station was used during World War II as a vehicle motor pool to support military operation. The motor pool operations were discontinued during the late 1940s or early 1950s. No records were available on the decommissioning of this motor pool or the removal of the associated UST.

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AOC 43J is situated on an access road that connects Patton Road and Queenstown Road in the central portion of the Main Post (Figure 1-2). The area around AOC 43J is presently unoccupied, but was recently a vehicle storage yard and maintenance facility (Building T-2446) for a Special Forces Unit of the U.S. Army. The yard and maintenance facility are paved with asphalt and surrounded by a chain-link fence with a locked gate located at the northern side of the yard (Figure 1-3).

Fort Devens ceased to be an active Army installation on September 30, 1995, as a result of BRAC. Although a small military presence will remain, a major portion of the post is in the process of being released for development. AOC 43J is located in a central portion of the main post that will remain Army property and will be within the Army Reserve Enclave.

Waste Oil UST Removal. In May 1992, ATEC Associates Inc. (ATEC) removed a 1,000-gallon waste oil UST approximately 50 feet east of the location of the 5,000-gallon gasoline UST (Figure 1-10). This 1,000-gallon UST was used by the former Special Forces unit for storage of waste oil generated from maintenance operations at this facility. Ten field screening samples (SS-1 through SS-10) and two laboratory analytical samples (LSS-1 and LSS-2) were collected from the side walls and bottom of the UST excavation to assess any possible effects from leaks and spills associated with the UST. Total volatile organic compound (VOC) concentrations (measured by a photoionization detector [PID] in sample container headspace) ranged from nondetect to 16.8 parts per million (ppm) and total petroleum hydrocarbon (TPHC) concentrations measured by nondispersed infrared (NDIR) spectroscopy ranged from 11.5 to 864.9 micrograms per gram ($\mu\text{g/g}$). Off-site laboratory analysis of samples collected from the excavation revealed TPHC concentrations of 74 $\mu\text{g/g}$ (LSS-1) and 918 $\mu\text{g/g}$ (LSS-2).

Under direction of a Fort Devens Environmental Management Office (EMO) representative, ATEC backfilled the excavation. The initial excavation was reportedly approximately 22 feet by 10 feet by 7 feet deep. In September 1992, additional soil was excavated per direction of the Massachusetts Department of Environmental Protection (MADEP) to reach background levels by PID (<1 ppm). The overall excavation final dimension was approximately 26 feet by 11.5 feet by 8 feet deep. Reportedly, 164 tons of waste oil contaminated soil were disposed at a soil recycling facility in Norridgewock, Maine (ATEC, 1992a). Six soil samples were obtained for laboratory analysis for TPHC by NDIR (four

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sidewall and two bottom samples). Two of the soil samples were also analyzed for VOCs and 13 priority pollutant metals by Toxicity Characteristic Leaching Procedure (TCLP) procedures. TPHC concentrations ranged between nondetect to 276 $\mu\text{g/g}$. The two samples (sidewall and bottom) analyzed for VOCs and TCLP revealed 5 and 9 $\mu\text{g/g}$ methylene chloride and 0.17 $\mu\text{g/g}$ zinc.

ATEC also installed four monitoring wells (2446-01 through 2446-04) around the former location the 1,000-gallon waste oil UST (Figure 1-10) to monitor the downgradient and upgradient groundwater quality. One round of groundwater samples was collected from these monitoring wells by ATEC. The samples were analyzed by a non-USAEC performance demonstrated laboratory for TPHC only. The results of the analyses show detectable concentrations of TPHC ranging from 3 milligrams per liter (mg/L) in 2446-04 to 140 mg/L in 2446-03. No TPHC was detected in 2446-01.

Historic Gas Station J Gasoline UST Removal. On August 26, 1992, ATEC removed a 5,000-gallon steel UST from historic gas station J (Figure 1-10). Visual observation of contaminated soil, as well as a strong fuel odor, were noted at the excavation (ATEC, 1992b). The initial excavation was reportedly 24 feet long by 13 feet wide, and was terminated at approximately 8 feet below ground surface (bgs) when groundwater was encountered. ATEC performed headspace screening for total VOCs by PID and for TPHC by NDIR on eight soil samples (SS-1 through SS-8) collected from the sides and bottom of the UST excavation. VOC concentrations ranged from 100 to 400 $\mu\text{g/g}$ in the sample headspace, and TPHC concentrations ranged from 43.9 to 3,534.8 $\mu\text{g/g}$ (ATEC, 1992b). No holes or breaks were found by the representatives from MADEP and Fort Devens EMO. There was an Underwriters Laboratory tag on the UST which indicated that this UST was younger than the reported age of historic gas station J.

Based on these field screening results, ATEC removed additional soil from this excavation. Excavation work was performed at the direction of the MADEP and EMO representatives to remediate soil to background levels by PID (<1 ppm) prior to obtaining additional soil samples for laboratory analysis. The overall excavation final dimension was approximately 28 feet by 18 feet by 8.5 feet deep. Groundwater was reportedly encountered at the north end of the excavation and bedrock was reached at the south end. From the observations made in the UST excavation, it appeared that the water table below the former UST was below the bedrock surface. Further lateral excavation was stopped during this cleanup

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process because of physical restrictions (e.g., driveway access, buildings, and stockpiled soil).

After the additional soil was removed from the excavation, ATEC collected four soil samples (LRS-1 through LRS-4) from the sidewalls (6 feet bgs); one soil sample (LSS-1) from the bottom of the UST excavation; and one water sample (LWS-1) from groundwater in the excavation for off-site laboratory analysis. Analysis of all samples, except LRS-3, was for TPHC. LRS-3 was analyzed for VOCs and TCLP Metals (extract). The results from LRS-3 indicated a xylene concentration of 1.65 $\mu\text{g/g}$ and 0.56 $\mu\text{g/g}$ ethylbenzene. TPHC concentrations reported for the other soil samples were nondetect, 38 $\mu\text{g/g}$, 1160 $\mu\text{g/g}$ (bottom sample) and 2,170 $\mu\text{g/g}$ (west wall). Groundwater sample LWS-1 contained 114 $\mu\text{g/g}$ of TPHC. The excavation was lined with polyethylene sheeting and backfilled with clean fill. ATEC completed these tasks and the area was then paved. Reportedly, 87 tons of gasoline contaminated soil were disposed at a soil recycling facility in Shrewsbury, Massachusetts (ATEC, 1992b, 1993).

1.2.2 Surficial and Subsurface Soil Geology

Surficial soils at AOC 43J are classified by the Soil Conservation Service (SCS) as part of the Hinckley-Freetown Windsor Association (SCS, 1991). Soils from this association in the immediate vicinity of AOC 43J were likely disturbed during construction of the paved motor pool area.

Figure 1-4 shows the orientation of geologic cross-sections. Figures 1-5 and 1-6 are cross-sections of A-A' and B-B', respectively. Based on the soil boring information collected at AOC 43J, it appears that fill soils were imported to level the original ground surface for construction of the motor pool area. Borings drilled at the site encountered fill soils ranging from 0.7 foot to 11 feet in thickness at XJM-93-04X (adjacent to the bedrock outcrop) and XJB-94-07X (located approximately 20 feet south of Building T2446), respectively (Figures 1-5 and 1-6). The fill thickness is relatively uniform beneath the site, except for the northwestern portion of the site where fill thickness decreases because of bedrock outcrop. These fill soils have variable colors (ranging from dark brown to light yellow brown to light olive gray) and textures (ranging from granular medium to coarse sands with subangular gravel to fine sand and silt). The fill soils are predominantly poorly graded, and medium dense to very dense.

Soil borings drilled at AOC 43J encountered a glacial till layer beneath the surficial soils and fill material. Depth to till near the former gasoline and waste oil USTs is approximately 9 feet. The till consists of a poorly sorted fine sandy silt, silty sand, or clayey silt, with coarse sand, fine to medium gravel, and occasional angular siltstone fragments and cobbles.

1.2.3 Bedrock Geology

Bedrock in the vicinity of AOC 43J is classified as the Oakdale formation (Zen, 1983). The formation is described as fine-grained metasiltstone and phyllite, consisting of quartz, and minor feldspar and ankerite. The metasiltstone and phyllite is commonly deformed by kink banding. Bedrock coring at AOC 43J was performed only at monitoring well boring XJM-93-04X (Figure 1-4). The boring log for XJM-93-04X indicates a dark gray to olive gray phyllite with secondary quartz stringers, and weathered, silt/till-filled fractures. Based on split-spoon samples and auger refusal, the bedrock surface at AOC 43J appears to be lightly to moderately weathered.

Visual observations at the site noted bedrock outcrops west and north of XJM-93-04X. Borings drilled at the site encountered bedrock from 0.7 foot to 58.5 feet bgs at XJM-93-04X and XJP-94-03X, respectively (Table 1-1). The bedrock surface appears to dip to the southeast between these two borings. The average interpreted depth to bedrock is relatively uniform at 15 feet to 20 feet bgs from southwest to northeast across the site (Figure 1-7).

A seismic refraction survey was performed during the RI at AOC 43J to further define the bedrock surface (Figure 1-3). Complete details of the methodology and results of the survey, including interpretive profiles of depth to bedrock, are presented in Appendix B of the RI Report (ABB-ES, 1996). The following paragraphs summarize the results and conclusions of this survey.

- The surface of the bedrock could be distinguished on all of the refraction records.
- The overburden at the site is unsaturated to fully saturated beginning at approximately 9 feet bgs. The uppermost layer has a velocity range of 1,000 to 1,700 feet per second, representative of unsaturated to slightly saturated silty sand and sand, and an

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intermediate layer with a range of 2,900 to 5,000 feet per second consisting of partially to fully saturated materials similar to the uppermost layer.

- The bedrock surface has moderately uniform slopes. The depth to bedrock ranges from zero to about 40 feet.
- Moderately competent to sound bedrock was detected on all profiles. The velocities of most of the bedrock, 15,000 to 19,000 feet per second, are indicative of a sound phyllitic bedrock, which is consistent with boring logs.
- One interval of moderately low bedrock velocity, 12,200 feet per second, was determined near SAJ06 and XJM-94-10X, indicative of more weathered bedrock than that profiled across the rest of the site.

In general, the depths to bedrock determined from the seismic survey are in relatively close (± 5 feet) agreement with physical data obtained from borings at AOC 43J. The major difference between the findings of the seismic refraction survey and the borehole geologic data is that the seismic data indicates that the bedrock surface is relatively flat between XJM-94-08X and XJP-94-03X/XJM-94-07X. However, Figure 1-7 indicates that the interpreted bedrock surface drops over 30 feet from XJM-94-08X to XJP-94-03X. The relatively flat, bedrock profile observed in the seismic data may be a result of dense glacial till (lodgement till), numerous boulders, or spacing of geophones.

1.2.4 Site Hydrology

AOC 43J is located in the south-central portion of Main Post on top of a topographic high. As a result, there are no surface water bodies (streams or ponds) in the immediate vicinity of the site. The area around the former UST is paved; however, a large portion of the site perimeter is unpaved. Based on topographic contours, precipitation runoff appears to be predominantly northwest to southeast across the site. Areas outside the paved area appear to be well drained, with no indication of seasonal ponding or wetlands environment.

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1.2.5 Site Hydrogeology

The water table at AOC 43J generally occurs in the till with the exception of the northwest corner of the site where the water table is present in the bedrock. Figures 1-8 and 1-9 show water table elevation contours for AOC 43J. The elevations referenced to mean standard sea level (MSL) were measured on January 31, 1995, and May 9, 1995, respectively. Based on the map that was compiled from May 9, 1995 data, groundwater flows predominantly to the south or southeast. It appears to flow radially from XJM-93-02X to the south and then eventually to the southeast. Water elevations varied quite substantially at XJM-93-02X from January to May. The elevation was 360.5 feet in January and 366.81 feet in May. This appears to be a seasonal condition (Table 1-2).

Hydraulic conductivity tests reveal that conductivity values for the till range from 2.9×10^3 cm/sec (centimeters per second) to 9.6×10^7 cm/sec. Assuming an effective porosity of 30 percent, estimated groundwater flow velocities range from 9×10^5 feet/day to 0.6 feet/day. The moderately slow groundwater flow velocities are consistent with the glacial till observed at AOC 43J. Table 1-3 presents a summary of monitoring well and piezometer completion details.

1.3 NATURE AND DISTRIBUTION OF CONTAMINATION

An SI, SSI, and an RI have been conducted by ABB-ES at AOC 43J.

May 1992 Site Investigation: This work focused on investigating the extent of soil contamination in and around the former gasoline UST located at historic gas station J. Activities performed during the SI are summarized below. Analyses of soil samples were for parameters listed in Table 1-4.

- A metal detector and a ground-penetrating radar survey were performed to confirm the presence or absence of the former gasoline UST. A 5,000-gallon UST was detected and later removed by ATEC in August 1992 (Subsection 1.2.1). Appendix B of the RI Report contains details of these surveys (ABB-ES, 1996).
- A total of eight TerraProbe™ points were completed around the former gasoline UST, and up to two soil samples per point were

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collected for field analysis of benzene, toluene, ethylbenzene, and xylenes (BTEX) and TPHC.

- One soil boring (43J-92-01X) was completed near the former gasoline UST and one subsurface soil sample was submitted for off-site laboratory analysis of project analyte list (PAL) VOCs, TPHC, and lead.

August 1993 Supplemental Site Investigation: This investigation focused on the soil in and around the former waste oil UST area located south of Building 2446, and the groundwater at AOC 43J (Figure 1-12). Major activities performed during the SSI are summarized below. Soil and groundwater samples were analyzed for parameters listed in Table 1-4.

- A total of 15 TerraProbe™ points (TS-11 through TS-14, TS-16 through TS-20, and TS-22 through TS-27) were completed near the former waste oil UST, and up to two soil samples per point were collected and analyzed in the field for BTEX and TPHC.
- Four groundwater monitoring wells (XJM-93-01X through XJM-93-04X) were installed to supplement the four existing monitoring wells for assessing any possible effects on groundwater from the former USTs.
- Soil samples were collected from three of the four monitoring well borings for off-site laboratory analysis of PAL VOCs, semivolatile organic compounds (SVOCs), inorganics, TPHC, and total organic carbon (TOC) to assess subsurface soil conditions in the vicinity of the UST areas.
- Two rounds of groundwater samples (Round Three and Four) were collected from the four newly installed monitoring wells and from three of the four existing monitoring wells (2446-02 through 2446-04) to assess potential effects on groundwater from the former USTs. These samples were for off-site laboratory analysis of PAL VOCs, SVOCs, inorganics (filtered and unfiltered), TPHC, and total suspended solids (TSS).

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August 1994 Remedial Investigation: This investigation focused on assessing the nature and distribution of contamination detected during the two previous investigations. Major activities performed during the RI are summarized below. Soil and groundwater samples were analyzed for the parameters listed in Table 1-4. Exploration locations are presented on Figures 1-3 and 1-13.

- A seismic refraction survey to further define the bedrock surface was performed.
- Drilling a total of 48 TerraProbe™ points east-southeast of the former UST locations, collecting up to two soil samples per point, and performing field analysis for selected chlorinated solvents, BTEX, and TPHC.
- Drilling 10 screened auger borings (SAJ01 through SAJ10) and collecting groundwater samples which were analyzed in the field for selected chlorinated solvents and BTEX.
- Drilling and sampling of 15 soil borings (XJB-94-02X through XJB-94-16X) for field analysis (selected chlorinated solvents, BTEX, and TPHC) and off-site laboratory analysis consisting of PAL VOCs, SVOCs, pesticides/PCBs, inorganics, TPHC, and TOC.
- Installing six monitoring wells (XJM-94-05X through XJM-94-10X).
- Collecting two rounds of groundwater sampling (Rounds Five and Six) from six new and seven existing monitoring wells for off-site laboratory analysis for PAL VOCs, SVOCs, inorganics (filtered and unfiltered), water quality parameters, and TSS.

1.3.1 Field Analytical Soil Results

TerraProbe™ Field Analytical Sample Results. Soil samples were collected for field analysis from TerraProbe™ points completed during the SI, SSI, and the RI field programs. SI and SSI TerraProbe™ soil samples were analyzed for BTEX and TPHC. RI TerraProbe™ soil samples were analyzed for BTEX, TPHC, and select chlorinated solvents to identify potential waste oil contaminants (Table 1-4).

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The following paragraphs discuss chronologically the TerraProbe™ soil sample field analytical results from these investigations.

During the SI a total of nine soil samples from TerraProbe™ points TS-01, TS-03, and TS-05 through TS-10 were collected and analyzed for BTEX and TPHC. The TerraProbe™ points could not be advanced deeper than 4 to 9 feet bgs because of subsurface obstruction and/or bedrock (Figure 1-11). Toluene, ethylbenzene, and xylenes (TEX) were detected in six of the nine samples collected, with individual concentrations ranging from nondetect up to 48 $\mu\text{g/g}$ total xylene, 16 $\mu\text{g/g}$ ethylbenzene, and 17 $\mu\text{g/g}$ toluene (all maximum concentrations were in TS-03 at 9 feet). Detection limits for TEX were 0.005, 0.010, and 0.005 $\mu\text{g/g}$, respectively. TPHC was detected in six of the nine samples at concentrations ranging from <55 to 940 $\mu\text{g/g}$.

During the SSI field investigation an additional 15 TerraProbe™ points (TS-11 through TS-14, TS-16 through TS-20, and TS-22 through TS-27) were completed. Soil samples were collected from 9 to 10 feet bgs (the apparent top of the bedrock), and analyzed for BTEX and TPHC. The points were concentrated in and around the former waste oil UST excavation in front of Building T-2446 (Figure 1-12). TEX were detected in 12 out of the 16 samples collected, with individual minimum and maximum concentrations ranging from 0.0008 $\mu\text{g/g}$ for o-xylene (TS-17, 8 feet) to 6.4 $\mu\text{g/g}$ for m/p-xylene (TS-25, 8 feet). Maximum detection limits for BTEX were reported to be 0.130, 0.130, 0.068, and 0.055 $\mu\text{g/g}$, respectively. TPHC was detected in five out of 16 samples, at concentrations ranging from 110 $\mu\text{g/g}$ (TS-22, 8 feet) to 3,100 $\mu\text{g/g}$ (TS-25, 8 feet). The distribution of the contamination was roughly defined on the northwest and west sides of the excavation; however, the northeast, east and southern sides were not defined fully during the SSI.

The RI field investigation of 1994 included the completion of an additional 48 TerraProbe™ points (Figure 1-13). Soil samples were collected from 7 to 9 feet and 9 to 11 feet bgs (at and below the water table) and analyzed for BTEX, TPHC, and select chlorinated solvents. The results of the field analyses indicate the presence of BTEX in soil primarily to the south of the waste oil UST excavation. BTEX was detected in 40 out of the 90 samples analyzed, with minimum and maximum concentrations ranging from 0.0028 $\mu\text{g/g}$ for toluene (TS-75, 7 feet) to 56 $\mu\text{g/g}$ for m/p-xylene (TS-67, 9 feet). The highest concentrations of total BTEX were found at TerraProbe™ points TS-31, TS-35, TS-43, TS-45, TS-

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53, TS-54, TS-56, TS-64, TS-66, TS-67, and TS-68. The values for total BTEX ranged from 17.5 $\mu\text{g/g}$ (9 feet) to 134 $\mu\text{g/g}$ (9 feet). TPHC was detected in 40 of the 90 samples at concentrations ranging from 74 $\mu\text{g/g}$ (TS-54, 9 feet) to 6,600 $\mu\text{g/g}$ (TS-35, 7 feet). Detection of TPHC was coincident generally with the detection of BTEX. 1,2-dichloroethene (1,2-DCE) was detected in one sample (TS-83, 9 feet) at a concentration of 0.0024 $\mu\text{g/g}$, which is just above the detection limit of 0.0022 $\mu\text{g/g}$.

Soil Boring Sample Results. Soil samples were collected for field analysis from each of the 15 soil borings (XJB-94-02X through XJB-94-16X) completed during the 1994 RI field investigation. The samples were taken at 5-foot intervals from each of the borings (except XJB-94-04X which was sampled continuously) and analyzed in the field for BTEX, TPHC, and selected chlorinated solvents (Table 1-4). BTEX was detected in 23 of 60 samples, with individual minimum and maximum concentrations ranging from 0.0031 $\mu\text{g/g}$ for toluene (XJB-94-12X, 9 feet) to 180 $\mu\text{g/g}$ for m/p-xylene (XJB-94-11X, 7 feet). The highest detected concentrations of total BTEX were found at soil borings XJB-94-03X, XJB-94-08X, and XJB-94-11X. TPHC was detected in 26 of the 60 samples at concentrations ranging from 100 $\mu\text{g/g}$ to 3,400 $\mu\text{g/g}$. Detection of TPHC was generally coincident with BTEX.

1.3.2 Off-Site Laboratory Analytical Soil Results

During the SI one soil boring was drilled and a soil sample analyzed to confirm the field analytical results. Laboratory analytical results for the soil sample collected from 43J-92-01X indicated that xylenes (0.022 $\mu\text{g/g}$) and TPHC (1,770 $\mu\text{g/g}$) were present. Lead was also present above Fort Devens background concentration.

During the SSI one soil sample from monitoring well borings XJM-93-01X through XJM-93-03X were submitted for off-site laboratory analysis. The only organic analytes detected in the soil samples collected from AOC 43J were probable laboratory contaminants such as acetone, di-n-butyl phthalate, and trichlorofluoromethane (freon). These were all detected at concentrations less than 0.15 $\mu\text{g/g}$. Acetone, di-n-butyl-phthalate, and trichlorofluoromethane (freon) were also detected in soil method blanks and trip blanks. Inorganic analytes exceeding Fort Devens background concentrations included arsenic, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium,

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sodium, and zinc. The majority of these analytes were detected in the 5- and 10-foot samples from XJM-93-02X. TPHC was detected at a concentration of 220 $\mu\text{g/g}$ in the 5-foot sample from XJM-93-02X only.

During the RI, the off-site laboratory results revealed that ethylbenzene was present in 7 of 31 samples at concentrations ranging from 0.0042 $\mu\text{g/g}$ (XJB-94-10X, 7 feet) to 30 $\mu\text{g/g}$ (XJB-94-11X, 7 feet). Toluene was detected in 5 of 31 samples at concentrations ranging from 0.1 $\mu\text{g/g}$ (XJB-94-08X, 7 feet) to 20 $\mu\text{g/g}$ (XJB-94-08X, 9 feet). Xylenes were detected in 7 of 31 samples at concentrations ranging from 0.0063 $\mu\text{g/g}$ (XJB-94-10X, 7 feet) to 100 $\mu\text{g/g}$ (XJB-94-08X, 9 feet). The highest concentrations of TEX were detected in soil borings XJB-94-03X (11 feet), XJB-94-08X (7 and 9 feet) and XJB-94-11X (7 and 11 feet). Detection of VOC tentatively identified compounds (TICs) and unknown compounds in soil boring samples is spatially consistent with detection of VOCs mentioned above and are indicative of fuel contamination.

SVOCs detected in the RI soil borings included methylnaphthalene, naphthalene, phenanthrene, and pyrene. 2-methylnaphthalene was detected in six of 31 samples, at concentrations ranging from 0.093 $\mu\text{g/g}$ (XJB-94-06X, 12 feet) to 7 $\mu\text{g/g}$ (XJB-94-11X, 7 feet). Naphthalene was detected in five of 31 samples, at concentrations ranging from 0.71 $\mu\text{g/g}$ (XJB-94-08X, 9 feet) to 10 $\mu\text{g/g}$ (XJB-94-11X, 7 feet). Phenanthrene and pyrene were detected in one soil sample (XJB-94-12X, 7 feet) at concentrations of 0.5 $\mu\text{g/g}$ and 0.7 $\mu\text{g/g}$, respectively.

TPHC was detected in 22 of 31 RI soil boring samples at concentrations ranging from 34.5 $\mu\text{g/g}$ (XJB-94-09X, 9 feet) to 1,880 $\mu\text{g/g}$ (XJB-94-11X, 7 feet). TPHC concentrations exceeded 500 $\mu\text{g/g}$ in soil samples collected from XJB-94-07X (11 feet, duplicate sample), XJB-94-11X (7 feet) and XJB-94-12X (7 feet).

Several inorganic analytes were detected above the Fort Devens background concentrations during the RI. Those included antimony, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, manganese, nickel, potassium, sodium, and zinc. The inorganic concentrations appear to be representative of AOC-related background.

1.3.3 Field Analytical Groundwater Results

Groundwater field analytical results were gathered only during the RI program from screened auger borings SAJ01 through SAJ10 (Figure 1-3). The results indicated that BTEX was present in samples collected from SAJ01, SAJ02, SAJ04, SAJ05, SAJ09 and SAJ10. Benzene was detected in 6 of 10 samples with concentrations ranging from 0.0038 $\mu\text{g/g}$ at SAJ01 to 0.46 $\mu\text{g/g}$ at SAJ04. Toluene was detected in 3 of 10 samples at concentrations ranging from 0.029 $\mu\text{g/g}$ at SAJ10 to 1.4 $\mu\text{g/g}$ at SAJ02. Ethylbenzene was detected in 4 of 10 samples at concentrations ranging from 0.005 $\mu\text{g/g}$ at SAJ09 to 2.3 $\mu\text{g/g}$ at SAJ02. M/p-xylene was detected in 4 of 10 samples at concentrations ranging from 0.005 $\mu\text{g/g}$ at SAJ09 to 1.8 $\mu\text{g/g}$ at SAJ02. O-xylene was detected in 5 of 10 samples at concentrations ranging from 0.003 $\mu\text{g/g}$ at SAJ09 to 0.68 $\mu\text{g/g}$ at SAJ02.

1.3.4 Off-Site Groundwater Laboratory Analytical Sample Results

Rounds Three and Four. Off-site laboratory analytical groundwater results for Round Three sampling indicated that several VOCs, including benzene, were present in three of the monitoring wells installed during the SSI as well as three of the existing monitoring wells (2446-02 to 2446-04). Total VOCs ranged from 8.9 micrograms per liter ($\mu\text{g/L}$) at XJM-93-02X to 18,200 $\mu\text{g/L}$ at 2446-02. Several SVOCs (2-methylnaphthalene, naphthalene and phenanthrene) and TPHC were also detected in these same monitoring well samples. Several inorganic analytes were detected above the Fort Devens background concentrations in the unfiltered and filtered samples. In the filtered samples, these included antimony, arsenic, calcium, iron, lead, magnesium, manganese, potassium, and sodium.

Off-site laboratory analytical groundwater results for Round Four sampling indicated that several VOCs (including benzene at concentrations ranging from 20.0 $\mu\text{g/L}$ to 200 $\mu\text{g/L}$) were present in three of the newly installed monitoring wells and in each of the existing monitoring wells. Total VOCs ranged from 240 $\mu\text{g/L}$ at XJM-93-03X to 23,000 $\mu\text{g/L}$ at 2446-02. Several SVOCs (2-methylnaphthalene, naphthalene and phenanthrene) and TPHC were also detected in these same monitoring wells. Several inorganic analytes were detected above the Fort Devens background concentrations in both the unfiltered and filtered samples. In the filtered samples, these included antimony, arsenic, calcium, iron, lead, magnesium, manganese, potassium, and sodium.

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SECTION 1

Rounds Five and Six. The results of Rounds Five and Six groundwater sampling indicated that several fuel-related and chlorinated solvents were present in the samples including BTEX, 1,2-dichloroethane, and carbon tetrachloride. Fuel-related VOCs were detected in monitoring wells 2446-02 to 2446-04, XJM-93-02X, XJM-93-03X, XJM-94-05X, XJM-94-08X, and XJM-94-09X in both rounds of sampling. Acetone, chloroform, and methylene chloride were detected also at low concentrations, but are probable laboratory contaminants because they were detected in method blanks, equipment rinsate, and trip blanks (ABB-ES, 1996). Benzene was detected at concentrations ranging from 0.56 $\mu\text{g/L}$ (XJM-94-08X) to 300 $\mu\text{g/L}$ (XJM-94-05X) in both rounds. Ethylbenzene was detected at concentrations ranging from 0.92 $\mu\text{g/L}$ (XJM-94-09X) to 3,000 $\mu\text{g/L}$ (2446-02 and 2446-03). Toluene was detected at concentrations ranging from 0.73 $\mu\text{g/L}$ (XJM-94-08X) to 7,000 $\mu\text{g/L}$ (2446-02). Xylenes were detected at concentrations ranging from 8.0 $\mu\text{g/L}$ (XJM-93-02X) to 8,000 $\mu\text{g/L}$ (2446-02).

1,2-dichloroethane was detected in monitoring well XJM-94-06X at a concentration of 23 $\mu\text{g/L}$ during Round Five and at 7.1 $\mu\text{g/L}$ in Round Six. 1,2-dichloroethane was not detected in any other monitoring wells at AOC 43J.

Carbon tetrachloride was detected in the Round Six samples in four monitoring wells (2446-03, 2446-04, XJM-94-05X and XJM-94-09X). Concentrations ranged from 3.3 $\mu\text{g/L}$ at XJM-94-09X to 100 $\mu\text{g/L}$ at XJM-94-05X. Carbon tetrachloride may have been present in previous rounds but gone undetected because of the relatively high detection limits from sample dilution (i.e., detection limits in Round Five were 80, 10, 30 and 0.58 $\mu\text{g/L}$ in the four monitoring wells, respectively. The following compounds were also detected in Rounds Five and Six: 1,2-dichlorobenzene at concentrations ranging from 4.8 $\mu\text{g/L}$ at 2446-04 to 14.0 $\mu\text{g/L}$ at XJM-93-02X; 1,4-dichlorobenzene at 3.6 $\mu\text{g/L}$ at XJM-93-02X only; 2,4-dimethylphenol was only detected once at 8.8 $\mu\text{g/L}$ at XJM-93-05X; 2-methylnaphthalene was detected at concentrations ranging from 6.2 $\mu\text{g/L}$ at XJM-93-02X to 100.0 $\mu\text{g/L}$ in 2446-02; 2-methylphenol (2-cresol) was detected in 2446-02 and XJM-94-05X at 5.3 $\mu\text{g/L}$ and 4.1 $\mu\text{g/L}$, respectively; 4-methylphenol (4-cresol) was also detected at 2446-02, 2446-03, and XJM-93-05X at concentrations ranging from 2.0 $\mu\text{g/L}$ to 3.9 $\mu\text{g/L}$. Naphthalene was also detected in these two rounds at concentrations ranging from 4.1 $\mu\text{g/L}$ at XJM-93-02X to 300 $\mu\text{g/L}$ at 2446-03. Possible sources of the fuel-related compounds are the former waste oil UST and the former gasoline UST. The source of the chlorinated VOCs is believed to be the former waste oil UST.

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The RI filtered sample results revealed that analytes such as antimony, arsenic, calcium, iron, magnesium, manganese, potassium, sodium, and zinc were all detected above Fort Devens background concentrations. TSS concentrations ranged from 8,000 $\mu\text{g/L}$ in XJM-93-04X to 3,130,000 $\mu\text{g/L}$ at 2446-02. Based on the high concentrations of TSS it appears that a large portion of the inorganic analytes detected in the unfiltered samples is a result of the TSS and not dissolved contaminants in groundwater.

1.3.5 Summary of Soil and Groundwater Analytical Results

Soil. Field analytical and off-site analytical laboratory data indicated that the former gasoline and waste oil USTs were the sources for the existing subsurface soil contamination at AOC 43J. Primary contaminants of concern detected in the subsurface soils were BTEX, 2-methylnaphthalene, naphthalene, phenanthrene, pyrene, and TPHC. These are documented constituents of gasoline and oils. Based on these results it appears that leaks and spills from both of the former USTs caused the existing soil contamination. The majority of contaminated soil was detected at, or just below, the water table at depths ranging from 7 to 12 feet bgs. Distribution of the subsurface soil contamination, as well as the groundwater flow directions of January and May 1995, support the USTs as source areas. Subsurface contamination was detected at higher concentrations at the water table with decreasing concentrations as sample depths increased. A summary of the chemicals of potential concern (CPCs) detected at AOC 43J is provided in Section 1.4, Summary of Human Health Risk Assessment of this report. Further discussion regarding the distribution of soil contamination in relation to remedial action objectives is provided in Section 2.0.

Groundwater. The distribution of the groundwater contamination confirms that the sources of groundwater contamination were the former historic gas station gasoline UST and the former waste oil UST, and that the existing groundwater contamination and residual soil contamination have migrated directly downgradient of the former UST locations.

BTEX, carbon tetrachloride, and several SVOCs were detected in several monitoring wells downgradient (2446-02, 2446-03, XJM-93-04X, XJM-94-05X, XJM-94-06X, and XJM-94-09X) of the former UST excavations.

SECTION 1

Groundwater organic contaminant distribution is similar to soil contaminant distribution. One discrepancy is that fuel-related contaminants have been detected intermittently in the bedrock monitoring well XJM-93-04X. Historically, XJM-93-04X contained fuel-related components (during Rounds Three and Four) since its initial sampling in 1993. However, concentrations decreased between Round Three and Four, and no fuel-related compounds were detected in this monitoring well during Round Five. However, Round Six data once again showed concentrations of fuel-related VOCs (BTEX). Contaminant degradation, seasonal fluctuations in groundwater elevation, and observed flow direction are possible factors in the fluctuating concentrations of fuel-related compounds in this monitoring well. With the exception of the initial detection of benzene in Round Three (70 $\mu\text{g/L}$), BTEX concentrations in XJM-93-04X have all been below federal and state drinking water standards.

A summary of the CPCs detected in AOC 43J groundwater is provided in Section 1.4, Summary of Human Health Risk Assessment. Further discussion regarding the distribution of groundwater contamination in relation to remedial action objectives is provided in Section 2.0.

1.4 SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

A baseline human health risk assessment was completed in the Final RI report, using soil and groundwater data collected during the SI, SSI, and RI, to evaluate potential health risks to individuals under current or foreseeable future site conditions at AOC 43J (ABB-ES, 1995). AOC 43J was evaluated as a source area comprised of the area in the immediate vicinity of the two removed USTs, and a perimeter area consisting of the remainder of the AOC.

1.4.1 Risk Assessment Considerations

Risk assessments were prepared to evaluate the following data:

- subsurface soil data collected from the source area and the perimeter area
- groundwater data collected from the source area
- groundwater data collected from downgradient areas

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The evaluation used appropriate subsurface soil data taken above 15 feet bgs from sample locations at the source and perimeter areas. Also considered were Rounds Five and Six groundwater analytical data from all source area and downgradient monitoring wells, with the exception of those monitoring wells identified as cross-gradient wells.

An exposure assessment was conducted to identify the potential pathways by which human receptors may be exposed to chemicals at AOC 43J. Exposures under both current and potential future site uses and surrounding land use conditions were evaluated. Future site and surrounding land use conditions were assumed to be similar to current conditions. AOC 43J is located on property which is being retained by the Army after base closure. The Army plans to use AOC 43J as a vehicle storage yard. The two buildings on the site (Buildings 2446 and 2479) will be demolished, and the underlying surface will be paved. It is also possible that in the future the site would be developed for commercial or industrial use, making new construction and/or utility line repair necessary.

For subsurface soil, two exposure scenarios were evaluated: a utility/maintenance worker engaged in periodic repair activities, and a construction worker involved in building activities on-site. The two principal routes by which workers could be exposed to chemicals in soil are ingestion and dermal contact.

Groundwater is not used currently in any way at AOC 43J. However, because future use cannot be ruled out, a future commercial/industrial worker using site groundwater (source area and downgradient area) as a drinking water source was selected as a receptor. Ingestion of groundwater as drinking water was the exposure route evaluated. Although unlikely, a future business might install a well on the site for use as a drinking water supply. The Devens Reuse Plan (Vanasse Hangen Brustlin, 1994) indicates that the area immediately downgradient (across Patton Road) will be retained by the federal government for use as the Federal Bureau of Prisons Medical Center. The cemetery, which is comprised of an approximate 450-by-350-foot parcel of land immediately across Patton Road will be retained as Army Reserve Enclave property. Drinking water supplies for residential recipients would not be expected within these immediate downgradient areas but cannot be ruled out for future commercial/industrial receptors. A recent delineation of Zone II aquifer areas, developed by tracing groundwater velocity vectors at Fort Devens, shows AOC 43J as being near the edge but within the Zone II aquifer area of the Sheboken Well (Koch, 1995).

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This delineation is only in draft form at this time and is still under investigation. AOC 43J is located approximately 4,000 feet from the Sheboken Well which is outside the 0.5 mile default radius.

Air could be a third contact medium if VOCs present in the soil or groundwater volatilize into the ambient air or if airborne particulates containing chemicals are generated from the soil. Inhalation of volatiles released from soil or groundwater was evaluated for both a future utility/maintenance worker and a future construction worker.

CPCs, identified for groundwater and subsurface soils, are presented in Table 1-5.

1.4.2 Subsurface Soil Data - Source Area

Risks associated with both current and future use of the site were evaluated assuming two exposure scenarios: a utility/maintenance worker engaged in periodic repair activities, and a construction worker involved in building activities on site. In both cases (utility/maintenance worker and construction worker) for current and future use, estimated carcinogenic risks did not exceed the USEPA target risk range of 1×10^{-4} to 1×10^{-6} or the MADEP Massachusetts Contingency Plan (MCP) target risk level of 1×10^{-5} . Similarly, estimated noncarcinogenic risks did not exceed the USEPA or MADEP target level of 1. Total carcinogenic and noncarcinogenic risks assuming exposure to mean and maximum concentrations are included in Table 1-6.

1.4.3 Subsurface Soil Data - Perimeter Area

Current and future risks associated with perimeter area subsurface soils were evaluated using the same scenarios described for source area subsurface soils. In the utility/maintenance worker and construction worker scenarios, estimated carcinogenic risks for exposures to subsurface soils within the perimeter area did not exceed the USEPA target risk range or the MCP target risk level. Similarly, estimated noncarcinogenic risks did not exceed the USEPA or MADEP target level. Total carcinogenic and noncarcinogenic risks assuming exposure to mean and maximum concentrations are included in Table 1-6.

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1.4.4 Groundwater Data - Source Area

Risks associated with the potential future use of site groundwater as a potable water source were evaluated using unfiltered and filtered data sets from source area monitoring wells. In each case, the receptor evaluated was a future commercial/industrial worker using site groundwater as a drinking water source. Estimated carcinogenic risks were found to be at the upper limit of or exceed the USEPA target risk range and the MCP target cancer risk level (Table 1-6).

Assuming exposures to mean concentrations, the estimated carcinogenic risk associated with unfiltered source area groundwater is 3×10^4 (Table 1-6). This exceeds both the USEPA target risk range and the MCP target cancer risk level. Arsenic is the primary contributor to the risk at 92 percent with an individual risk of 2.4×10^4 . Benzene (4 percent) and carbon tetrachloride (3 percent) contribute the remainder, with respective risks of 1×10^5 and 9.1×10^6 . The estimated risk assuming exposure to maximum concentrations is 6×10^4 . Arsenic (86 percent), carbon tetrachloride (7 percent) and benzene (5 percent) are the primary contributors, with 5.4×10^4 , 4.5×10^5 , and 3.0×10^5 individual risks, respectively.

The estimated carcinogenic risk associated with filtered source area groundwater assuming exposure to mean concentrations is 2×10^4 . Arsenic contributes 90 percent of the risk, with benzene and carbon tetrachloride contributing 5 percent and 4 percent, respectively. Individual cancer risks are 1.9×10^4 for arsenic, 1×10^5 for benzene, and 9.1×10^6 for carbon tetrachloride. The estimated cancer risk assuming exposure to maximum concentrations is 5×10^4 . Arsenic (84 percent), benzene (6 percent), and carbon tetrachloride (9 percent) are the major risk contributors; their respective individual risks are 4.4×10^4 , 3×10^5 , and 4.5×10^5 .

Estimated noncarcinogenic risk, expressed as hazard index (HI) values, also exceed the USEPA and MADEP target level. The noncarcinogenic HI value for unfiltered source area groundwater is estimated at 25 assuming exposures to mean concentrations, and at an HI of 53 for exposures to maximum concentrations. Based on mean concentrations, the primary contributors to noncarcinogenic risk are manganese at 76 percent, benzene at 13 percent, and arsenic at 5 percent. Respective hazard indices are 19, 3.2, and 1.2. For maximum concentrations, the contributors to noncarcinogenic risk are manganese at 67 percent, benzene at 18

SECTION 1

percent, arsenic at 5 percent, and iron and carbon tetrachloride at 3 percent. Respective hazard indices are 36, 9.8, 2.9, 1.6, and 1.4.

The noncarcinogenic HI value for filtered source area groundwater is estimated at an HI of 24 assuming exposures to mean concentrations, and at an HI of 52 for exposures to maximum concentrations. The primary contributors to the noncarcinogenic risk based on mean concentrations are manganese at 78 percent and benzene at 13 percent with hazard indices of 19 and 3.2, respectively. For maximum concentrations, the contributors to noncarcinogenic risk are manganese at 70 percent, benzene at 19 percent, arsenic at 5 percent, and carbon tetrachloride at 3 percent. Respective hazard indices are 36, 9.8, 2.4, and 1.4.

1.4.5 Groundwater Data - Downgradient

Risks associated with the potential future use of site groundwater as a potable water source were evaluated using unfiltered and filtered data sets from downgradient wells. In each case, the receptor evaluated was a future commercial/industrial worker using site groundwater as a drinking water source. Estimated carcinogenic risks were found to be at the upper limit of or exceed the USEPA target risk range and the MCP target cancer risk level (Table 1-6).

The estimated carcinogenic risk associated with unfiltered downgradient groundwater is 3×10^{-5} assuming exposure to mean concentrations and 7×10^{-5} assuming exposure to maximum concentrations. Both are within the USEPA risk range, but slightly exceed the MCP target level. Arsenic contributes 97 percent of the risk assuming exposure to mean concentrations and is the only CPC with an individual cancer risk exceeding 1×10^{-6} . Assuming exposure to maximum concentrations, arsenic contributes 95 percent of the risk and benzene and carbon tetrachloride add 3 percent and 2 percent, respectively. Individual risks are 7×10^{-5} , 2×10^{-6} , and 1.5×10^{-6} , respectively.

The estimated cancer risk associated with filtered downgradient groundwater assuming exposure to mean concentrations is 6×10^{-7} , which is below both the USEPA risk range and the MCP target level. For exposure to maximum CPC concentrations, the total cancer risk is 4×10^{-6} , which is within the USEPA risk range and below the MCP target risk level.

Estimated noncarcinogenic exposures exceeded the USEPA and MADEP target level for both filtered and unfiltered downgradient groundwater. The noncarcinogenic HI value for unfiltered downgradient groundwater is estimated at 2 assuming exposures to mean concentrations, and at 7 for exposures to maximum concentrations. Based on mean concentrations, manganese contributes 77 percent with an individual hazard index of 1.5. For exposures to maximum concentrations, manganese contributes 68 percent with a hazard index of 4.6. Manganese is the only CPC with an individual hazard index greater than 1.0 for both mean and maximum concentration scenarios.

The noncarcinogenic HI value for filtered downgradient groundwater is estimated at 2 assuming exposures to mean concentrations, and at 6 for exposures to maximum concentrations. The primary risk contributor based on mean concentrations is manganese, at 91 percent with a hazard index of 1.5. For exposures to maximum concentrations, manganese contributes 87 percent of the risk with a hazard index of 5.4. Again, manganese is the only CPC with an individual hazard index greater than 1.0 for both mean and maximum concentration scenarios.

1.4.6 Vapor Migration

To evaluate qualitatively whether vapor migration may represent a future risk, concentrations of volatiles in source and downgradient groundwater were compared to MCP Method 1 GW-2 standards. If average groundwater concentrations are compared to the GW-2 standards, as required under the MCP, the average concentrations of all detected VOCs are equal to or below the GW-2 standards. Vapor migration into building foundations is not expected to pose a significant risk at AOC 43J.

1.5 ECOLOGICAL RISK

A baseline ecological risk assessment was not completed for AOC 43J because no significant habitat for resident or migratory ecological receptors are anticipated to be present at AOC 43J, and contamination is limited predominantly to subsurface soil and groundwater. The site is mostly paved and has been used historically as a gas station.

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FEASIBILITY STUDY REPORT

ALTERNATIVE SCREENING REPORT

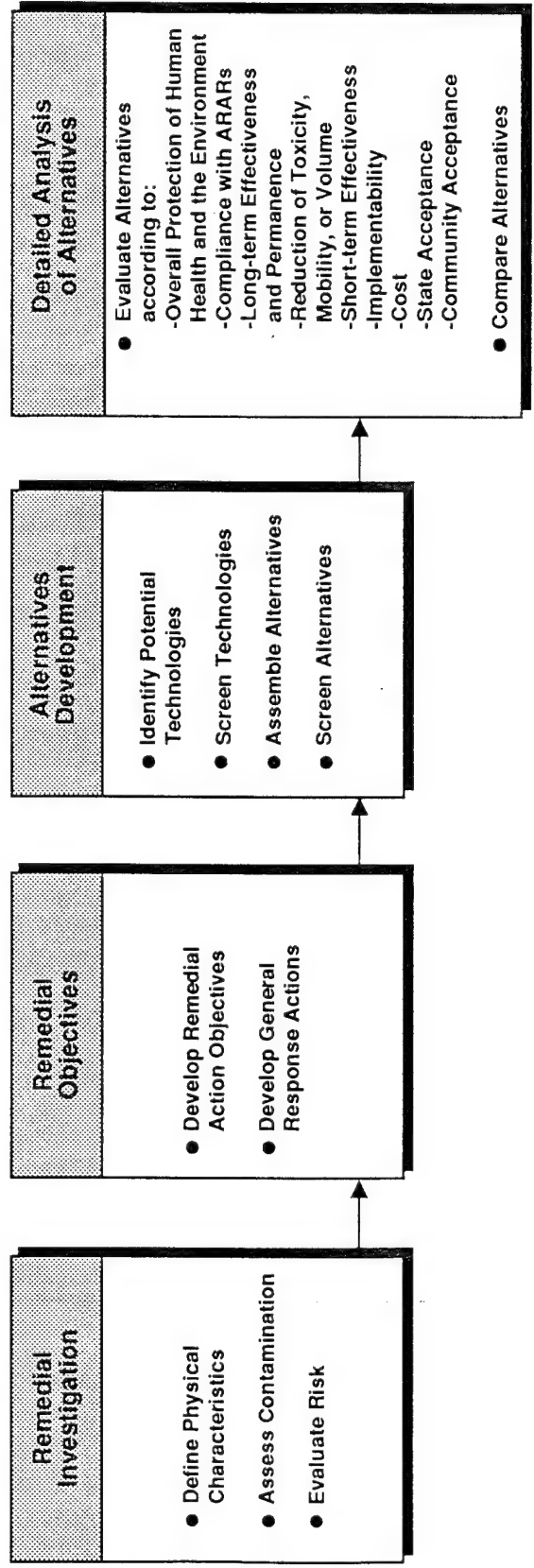
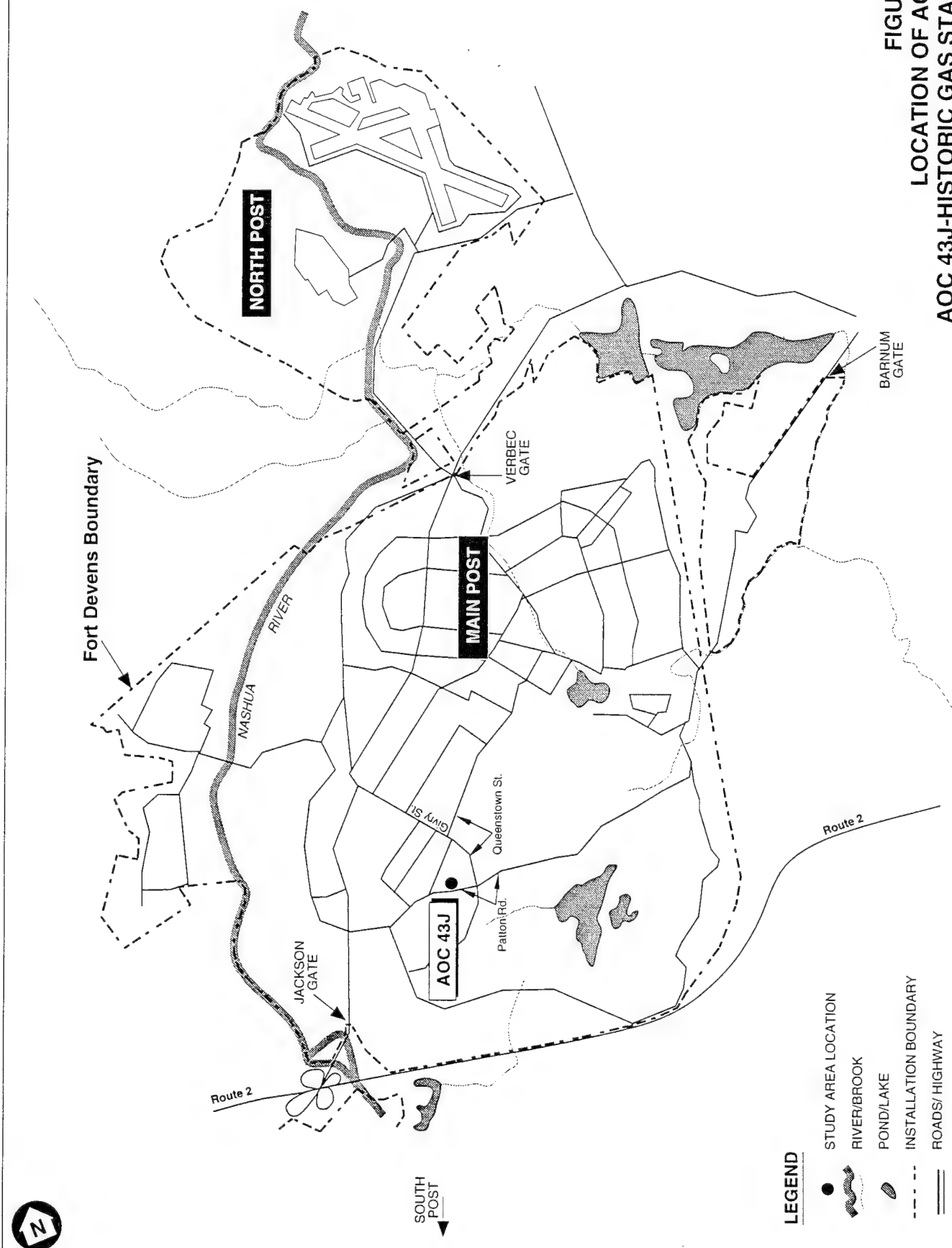


FIGURE 1-1
FEASIBILITY STUDY PROCESS
AOC 43J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA
ABB ENVIRONMENTAL SERVICES, INC.



LEGEND

- STUDY AREA LOCATION
- ~ RIVER/BROOK
- ◐ POND/LAKE
- - - INSTALLATION BOUNDARY
- == ROADS/HIGHWAY



FIGURE 1-2
LOCATION OF AOC 43J
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA

ACCESS

ROAD

EDGE OF ASPHALT PAVEMENT

GRASS AND TREES

WASTE OIL UST
EXCAVATION

STORAGE CONTAINERS

ONE-STORY
WOODEN BLDG.
T2446

CHAIN LINK FENCE

BEDROCK OUTCROP

XJM-93-01X

XJM-93-02X

PAVED AREA

GASOLINE UST
EXCAVATION

ASPHALT BERM

BEDROCK OUTCROP

BEDROCK OUTCROP

GRASS AND TREES

XJM-93-04X

XJB-94-05X
XJB-94-06X

2446-03

XJB-94-09X

XJB-94-08X

2446-02

SAJ02/XJB-94-03X

XJM-94-05X

XJP-94-01X

XJB-94-10X

XJM-93-03X

XJB-94-11X

XJP-94-02X

XJB-94-14X

SAJ04/XJB-94-02X

XJM-94-09X

XJB-94-12X

XJB-94-13X

SAJ10

XJM-94-10X

SAJ06

XJB-94-15X

SAJ07

SAJ08/XJB-94-11X

XJB-94-15X

SAJ07

PAVED AREA

PATTON

ROAD

0 25 50 100 FEET

SCALE: 1"=50'

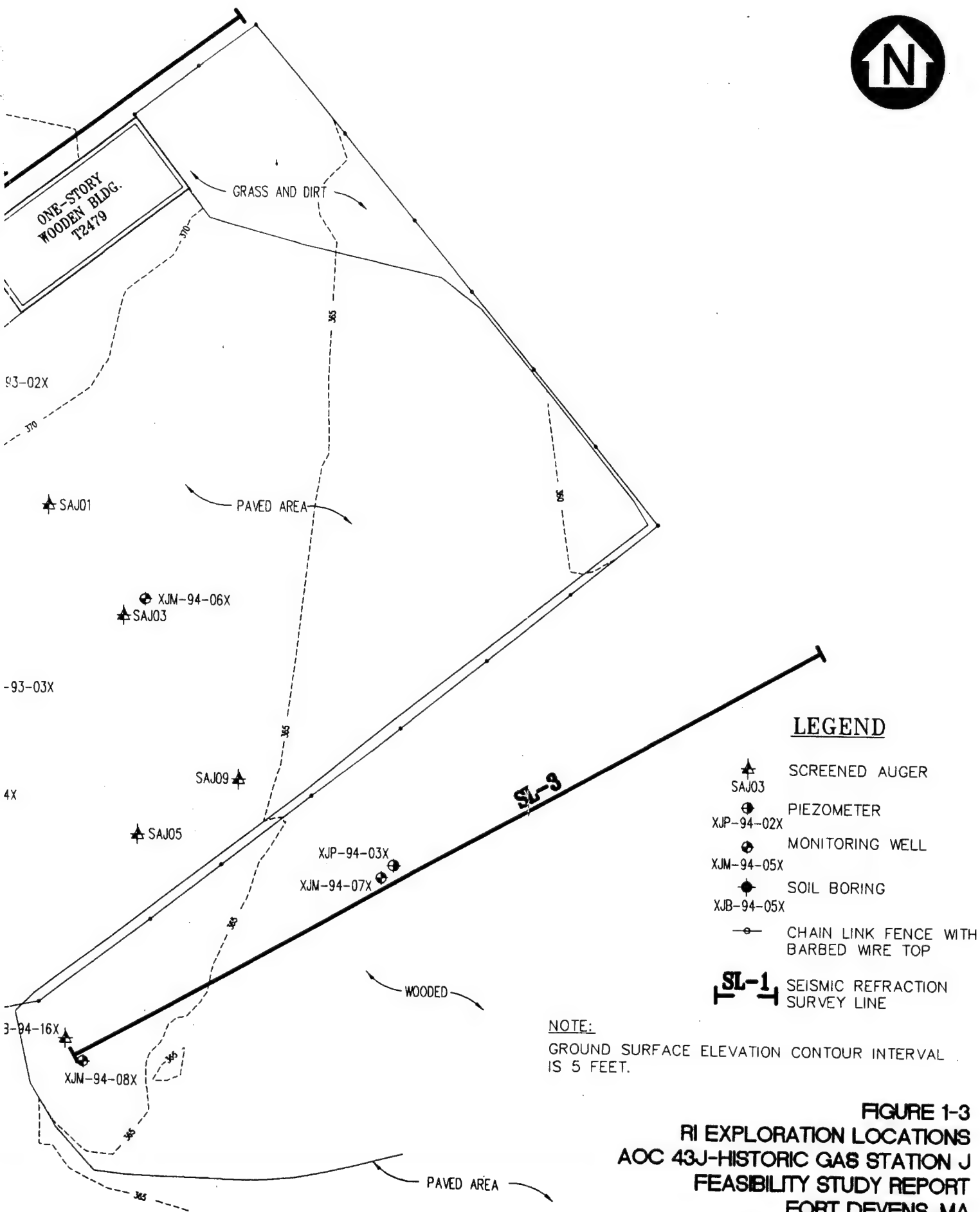
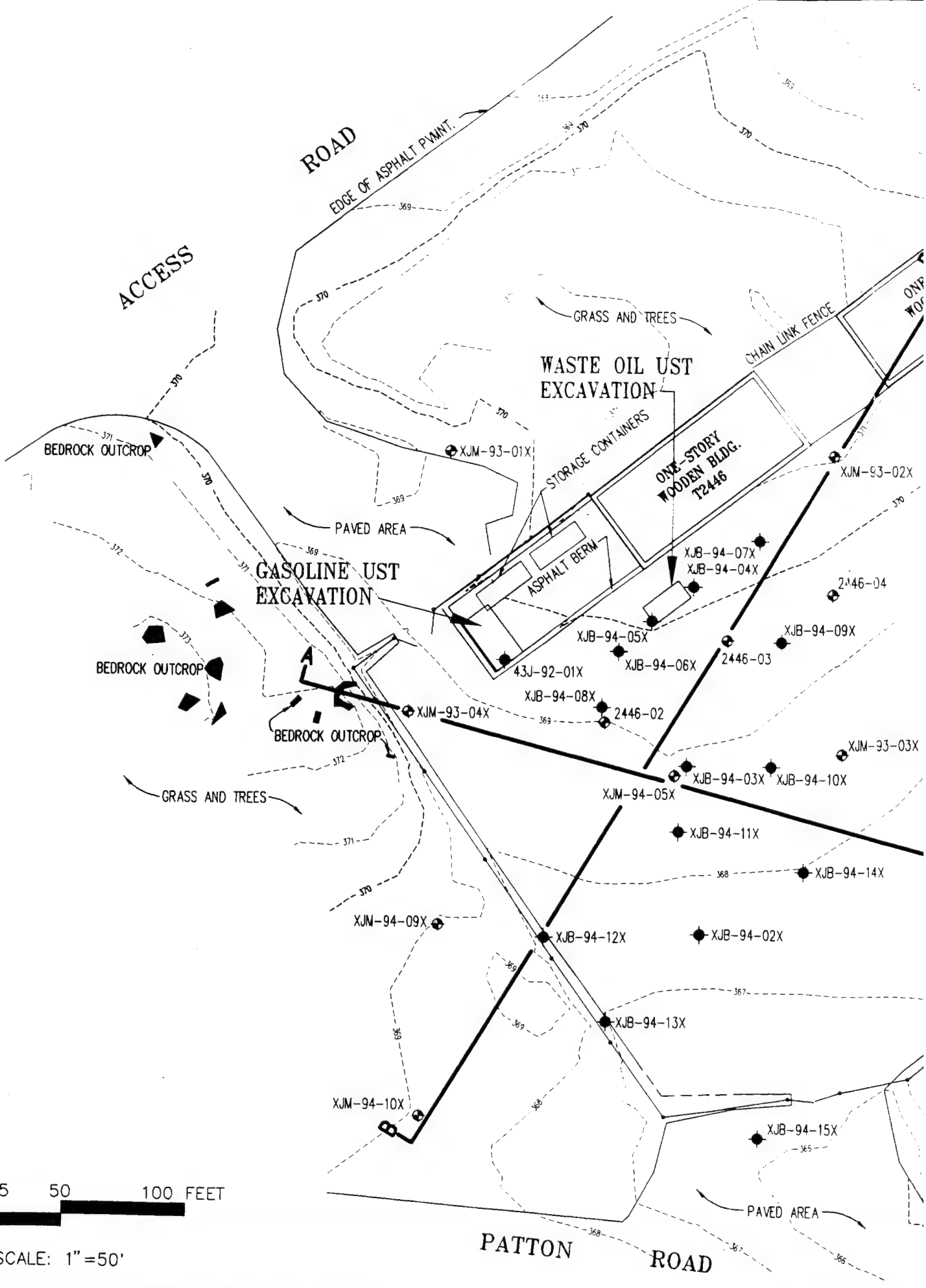
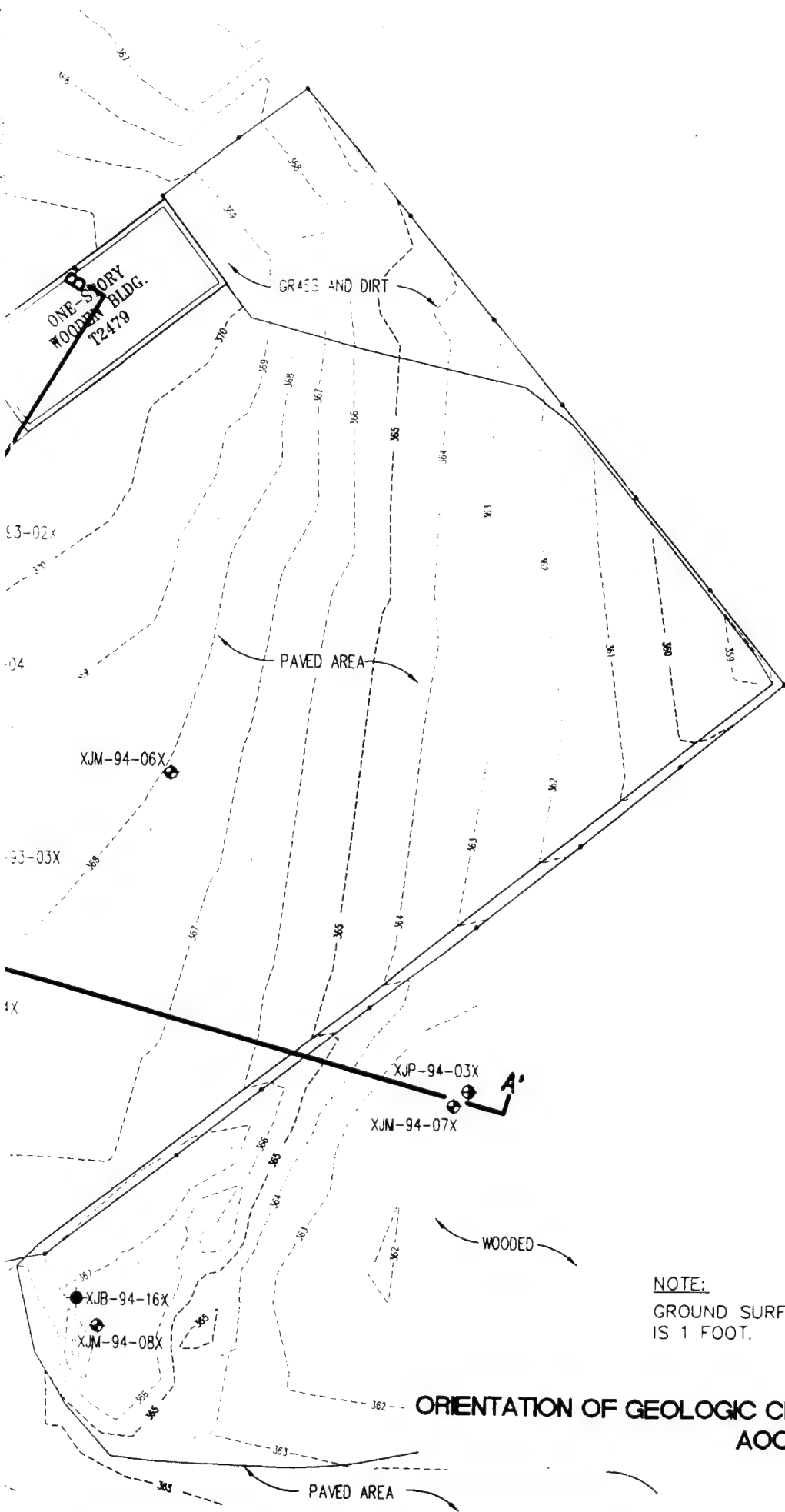


FIGURE 1-3
RI EXPLORATION LOCATIONS
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA








0 25 50 100 FEET

SCALE: 1"=50'



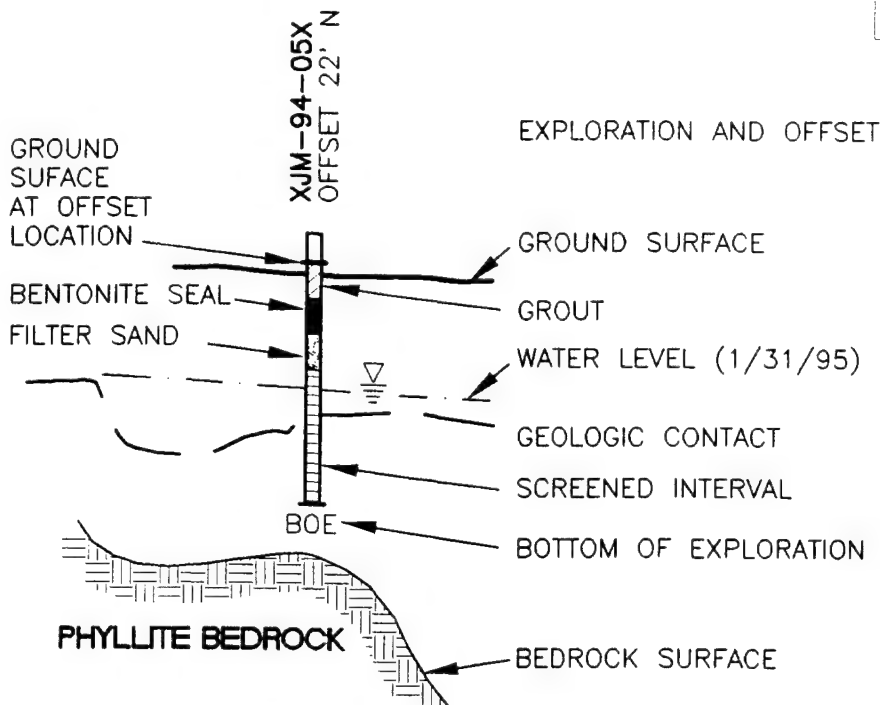
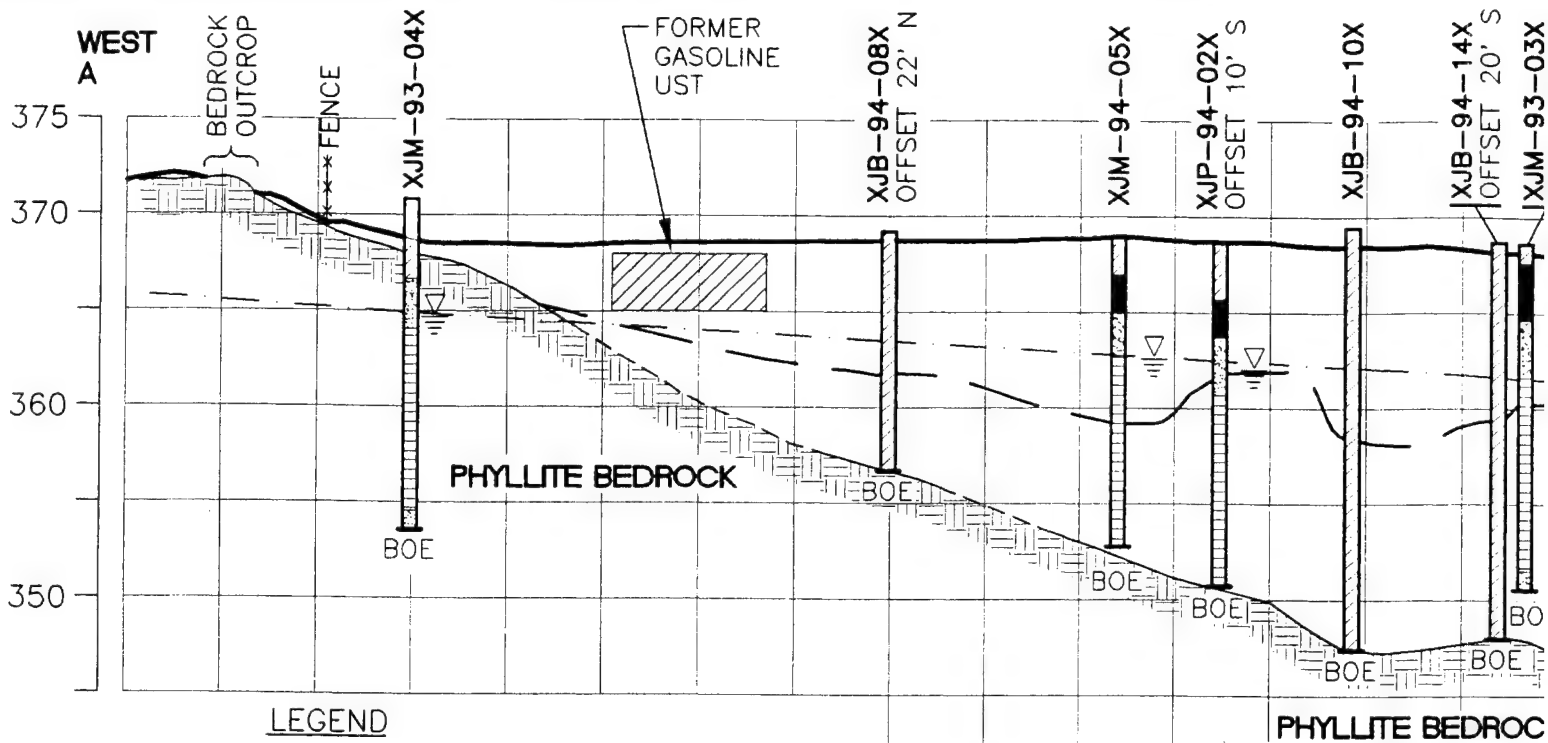
LEGEND

-  PIEZOMETER
-  MONITORING WELL
-  SOIL BORING
-  CROSS SECTION ORIENTATION
-  CHAIN LINK FENCE WITH BARBED WIRE TOP

NOTE:

GROUND SURFACE ELEVATION CONTOUR INTERVAL IS 1 FOOT.

FIGURE 1-4
ORIENTATION OF GEOLOGIC CROSS SECTIONS A-A' AND B-B'
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA



NOTES:

1. FOR ORIENTATION OF CROSS SECTION SEE FIGURE 1-4.
2. TILL COMPOSED OF POORLY GRADED SAND GRADING DOWNWARD TO SILTY SAND WITH CLAY AND WEATHERED PHYLLITE.
3. DUE TO ITS WEATHERED NATURE THE BEDROCK SURFACE WAS DEFINED BY SPLIT-SPOON/AUGER REFUSAL.
4. GEOLOGIC CONDITIONS BETWEEN WELLS ARE AN INTERPRETATION OF AVAILABLE DATA. ACTUAL CONDITIONS MAY VARY.
5. XJP-94-03X WAS COMPLETED AS A BORING, NO PIEZOMETER WAS INSTALLED.

0 15 30 60
HORIZONTAL SCALE: 1" =
VERTICAL SCALE: 1" = 1
VERTICAL EXAGGERATION:

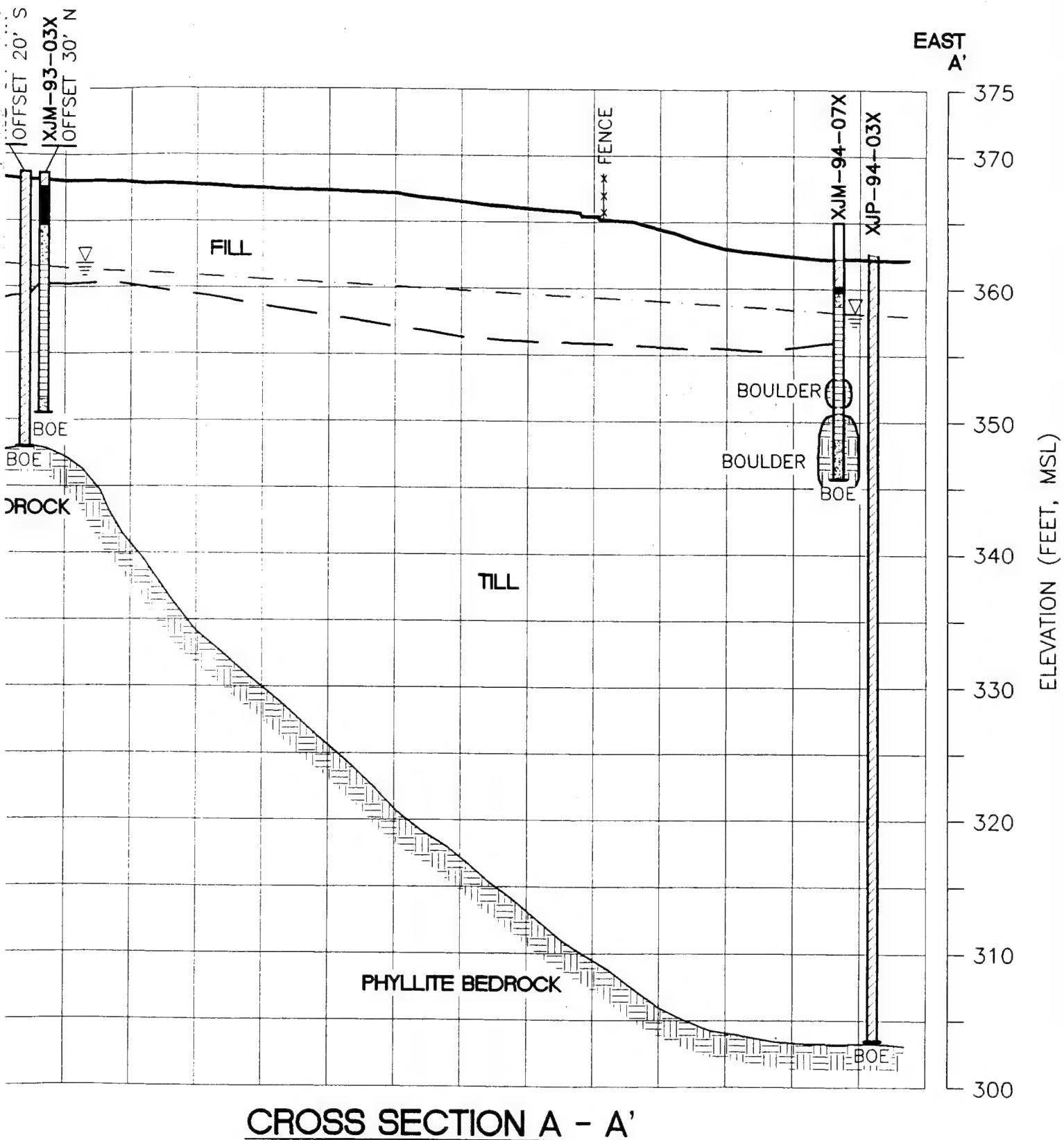
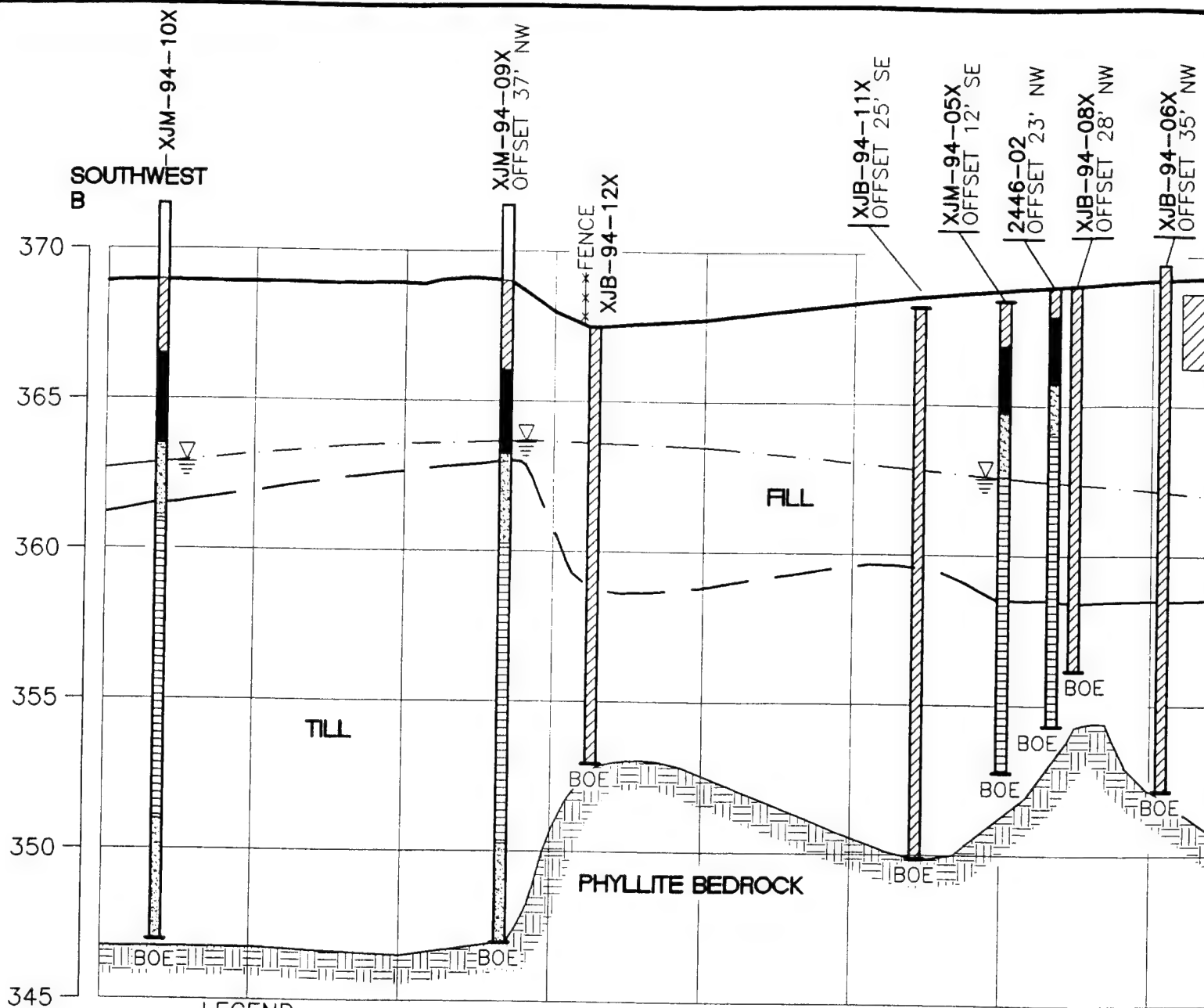
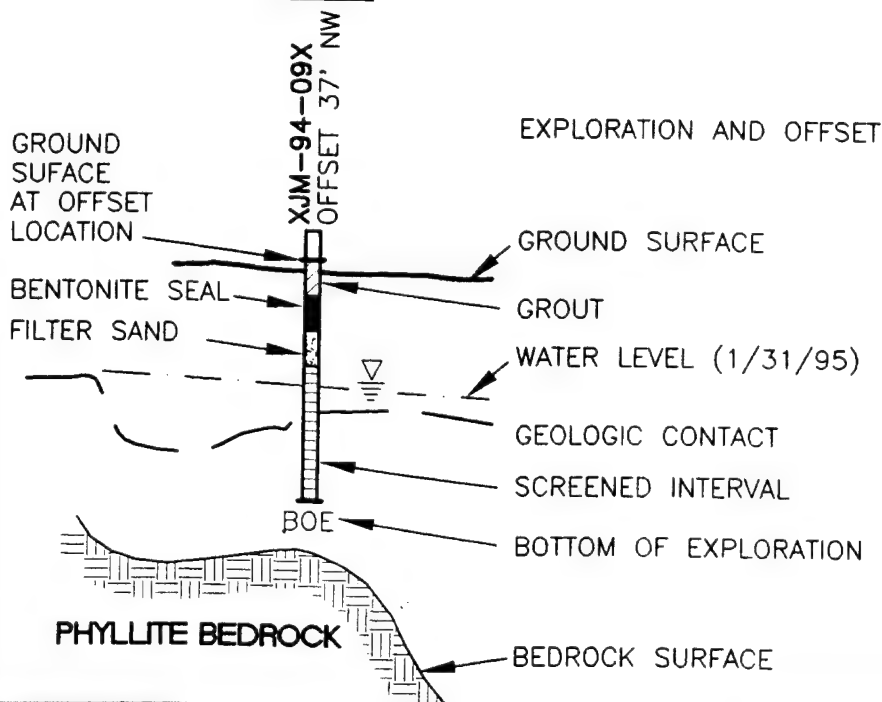


FIGURE 1-5
INTERPRETIVE GEOLOGIC CROSS SECTION A-A'
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA

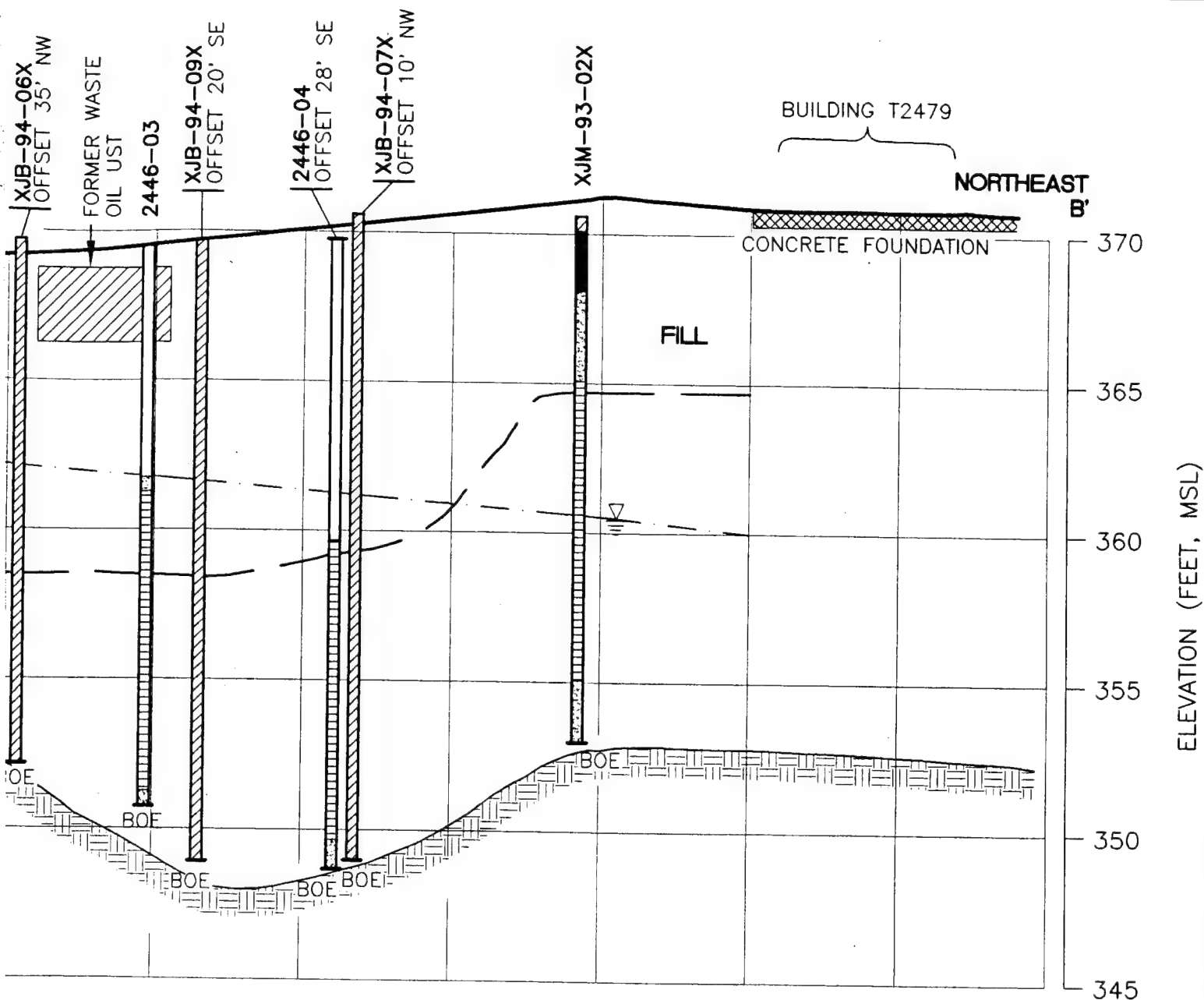


CROSS SECTION



NOTES:

1. FOR ORIENTATION OF CROSS
2. TILL COMPOSED OF POORLY TO SILTY SAND WITH CLAY A
3. DUE TO ITS WEATHERED, NAT WAS DEFINED BY SPLIT-SPO
4. GEOLOGIC CONDITIONS BETWE AVAILABLE DATA. ACTUAL CON
5. BEDROCK ELEVATION DATA BE IS INFERRED FROM SEISMIC I



ON B - B'

0 15 30 60 FEET

CROSS SECTION SEE FIGURE 1-4.

ORLY GRADED SAND GRADING DOWNWARD
AY AND WEATHERED PHYLLITE.

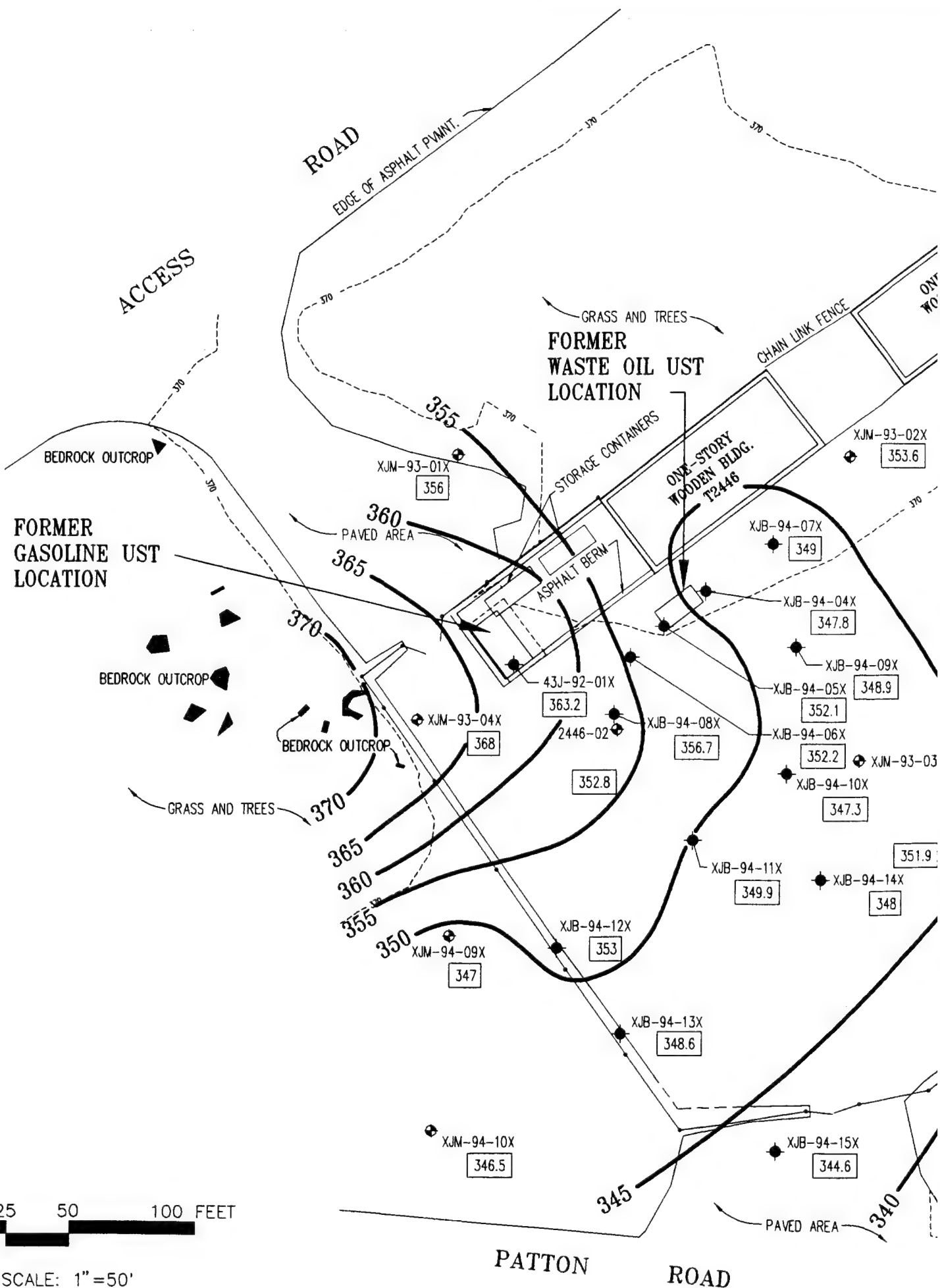
, NATURE THE BEDROCK SURFACE
-SPOON/AUGER REFUSAL.

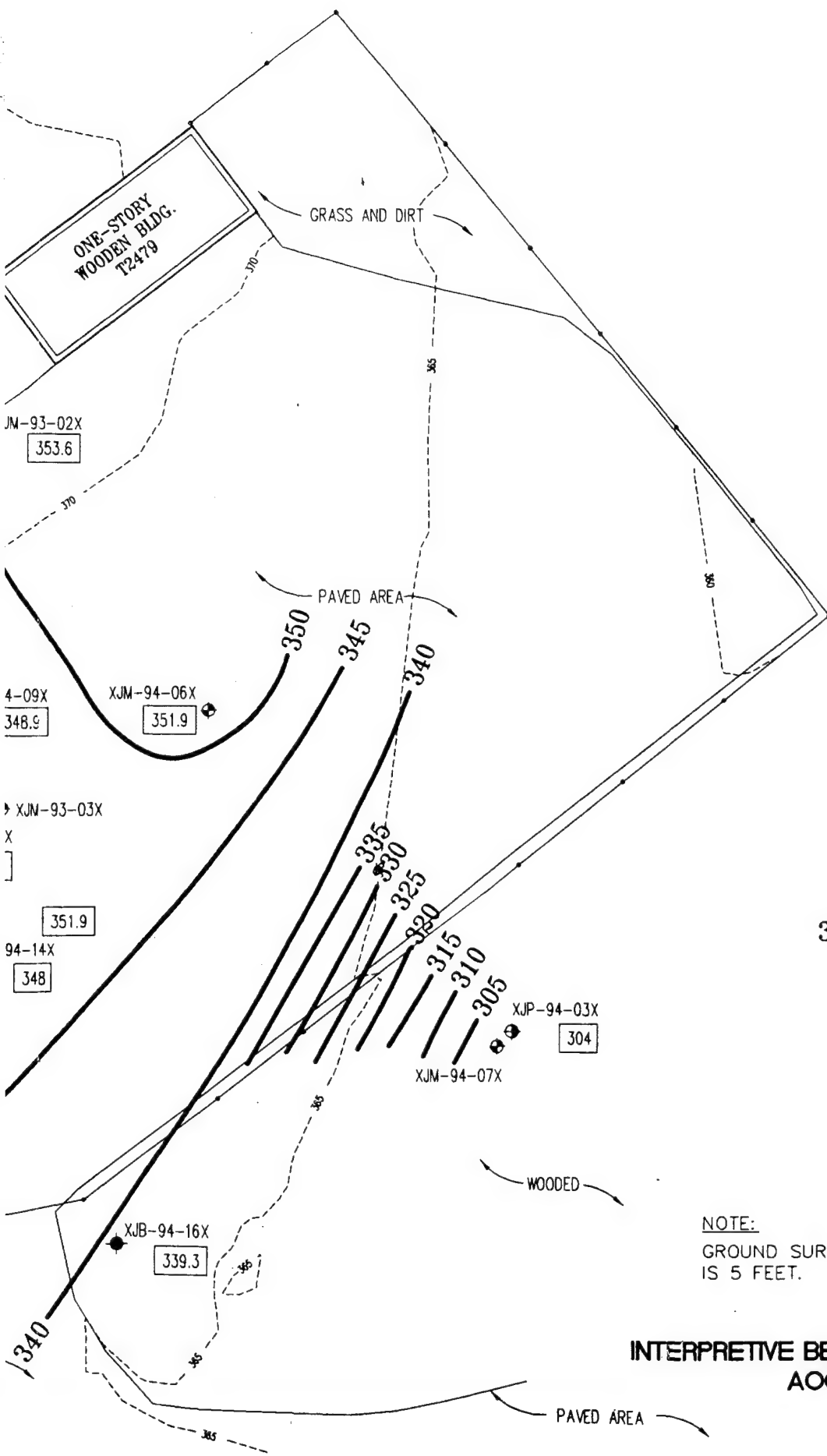
BETWEEN WELLS ARE AN INTERPRETATION OF
CONDITIONS MAY VARY.

TA BENEATH BUILDING T2479
MIC REFRACTION SURVEY DATA.

HORIZONTAL SCALE: 1"=30'
VERTICAL SCALE: 1"=10'
VERTICAL EXAGGERATION: 3:1

FIGURE 1-6
INTERPRETIVE GEOLOGIC CROSS SECTION B-B'
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA





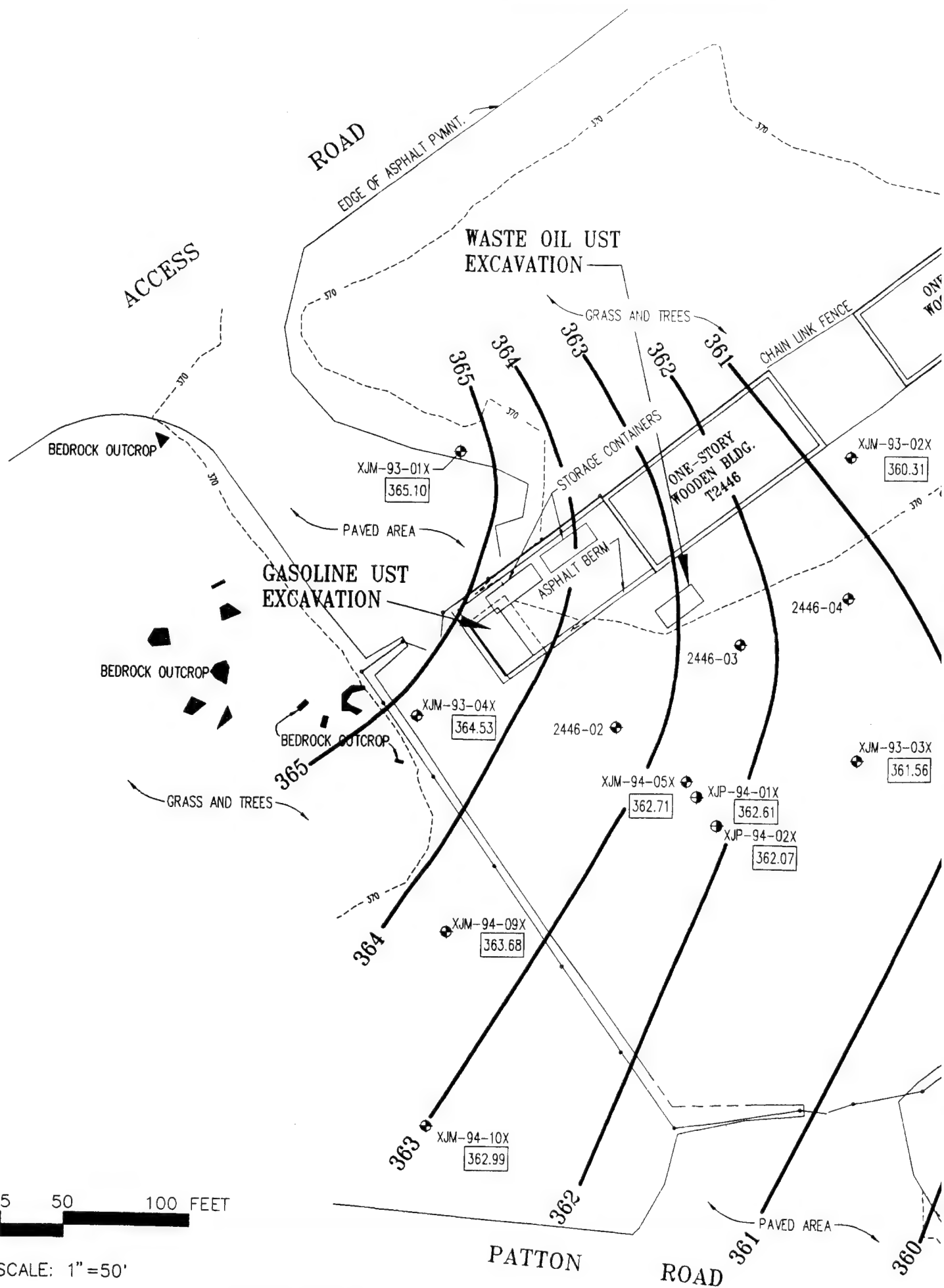
LEGEND

- 345 — INTERPRETIVE BEDROCK ELEVATION CONTOUR
- 346.5 ELEVATION OF BEDROCK
- MONITORING WELL
- SOIL BORING
- CHAIN LINK FENCE WITH BARBED WIRE TOP

NOTE:

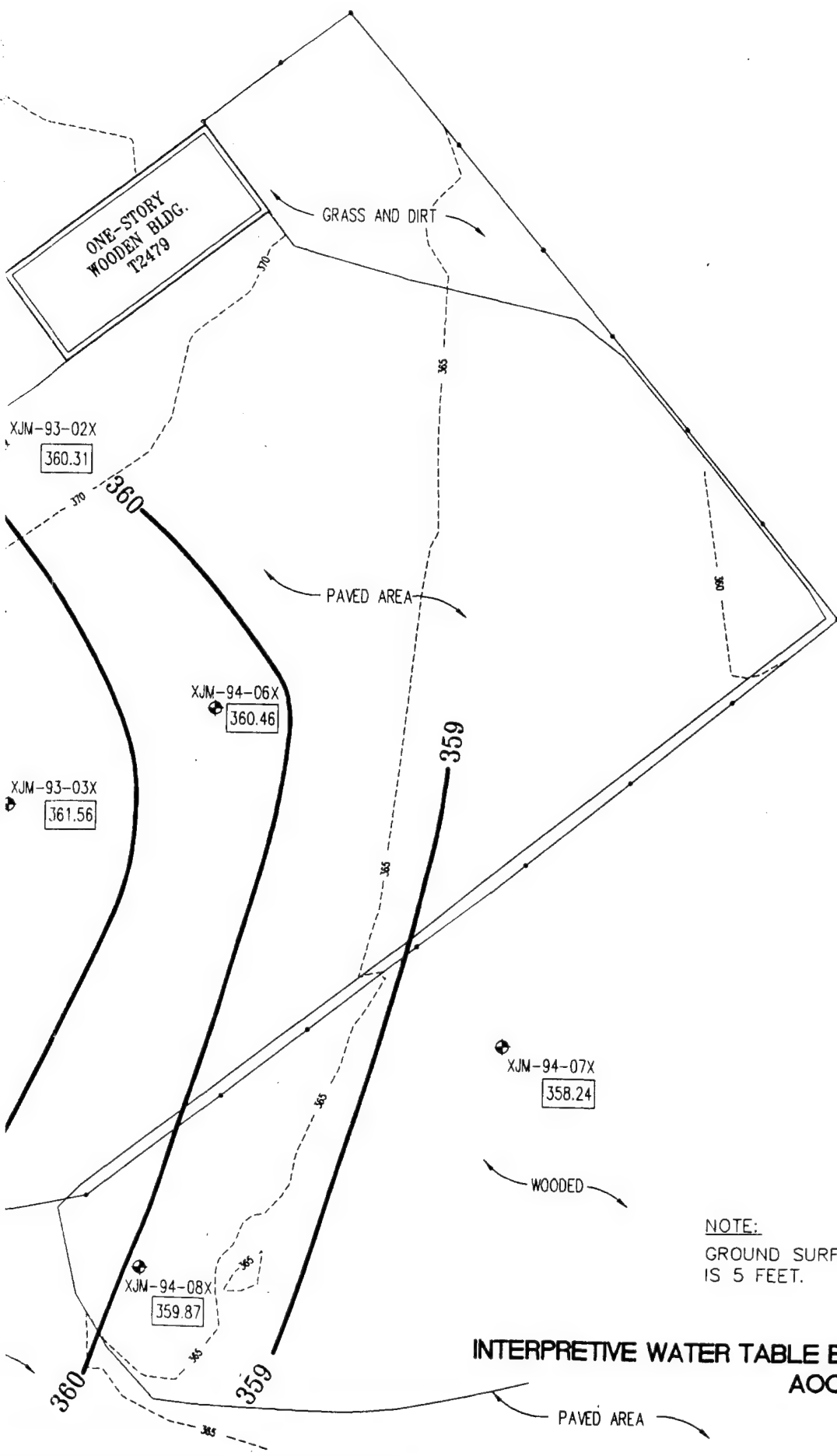
GROUND SURFACE ELEVATION CONTOUR INTERVAL IS 5 FEET.

FIGURE 1-7
INTERPRETIVE BEDROCK ELEVATION CONTOURS
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA



0 25 50 100 FEET

SCALE: 1"=50'



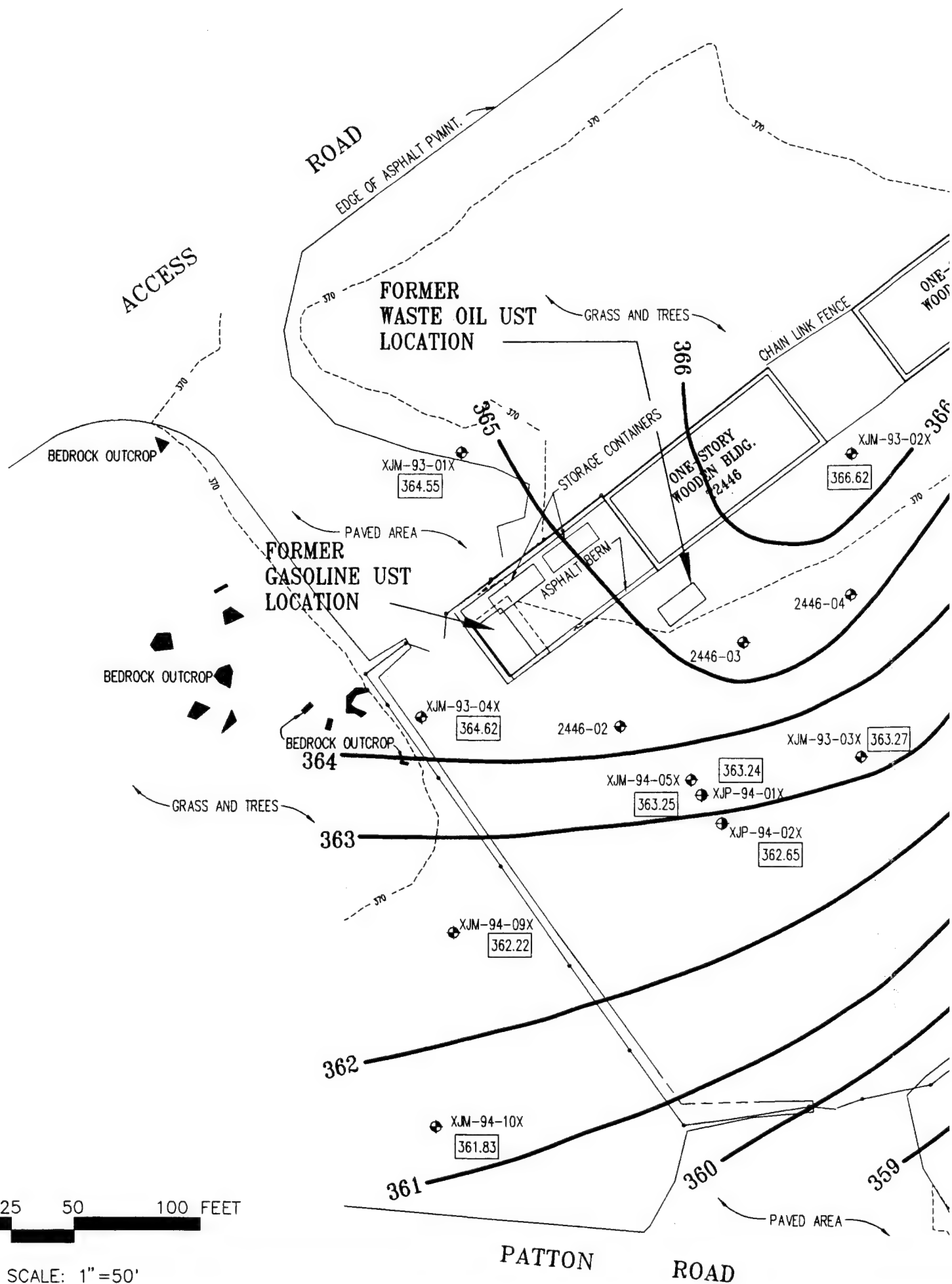
LEGEND

- 362 — INTERPRETIVE WATER TABLE ELEVATION CONTOUR
- 362.96 ELEVATION OF GROUNDWATER JAN 31, 1995
- XJM-94-02X PIEZOMETER
- XJM-94-05X MONITORING WELL
- CHAIN LINK FENCE WITH BARBED WIRE TOP

NOTE:

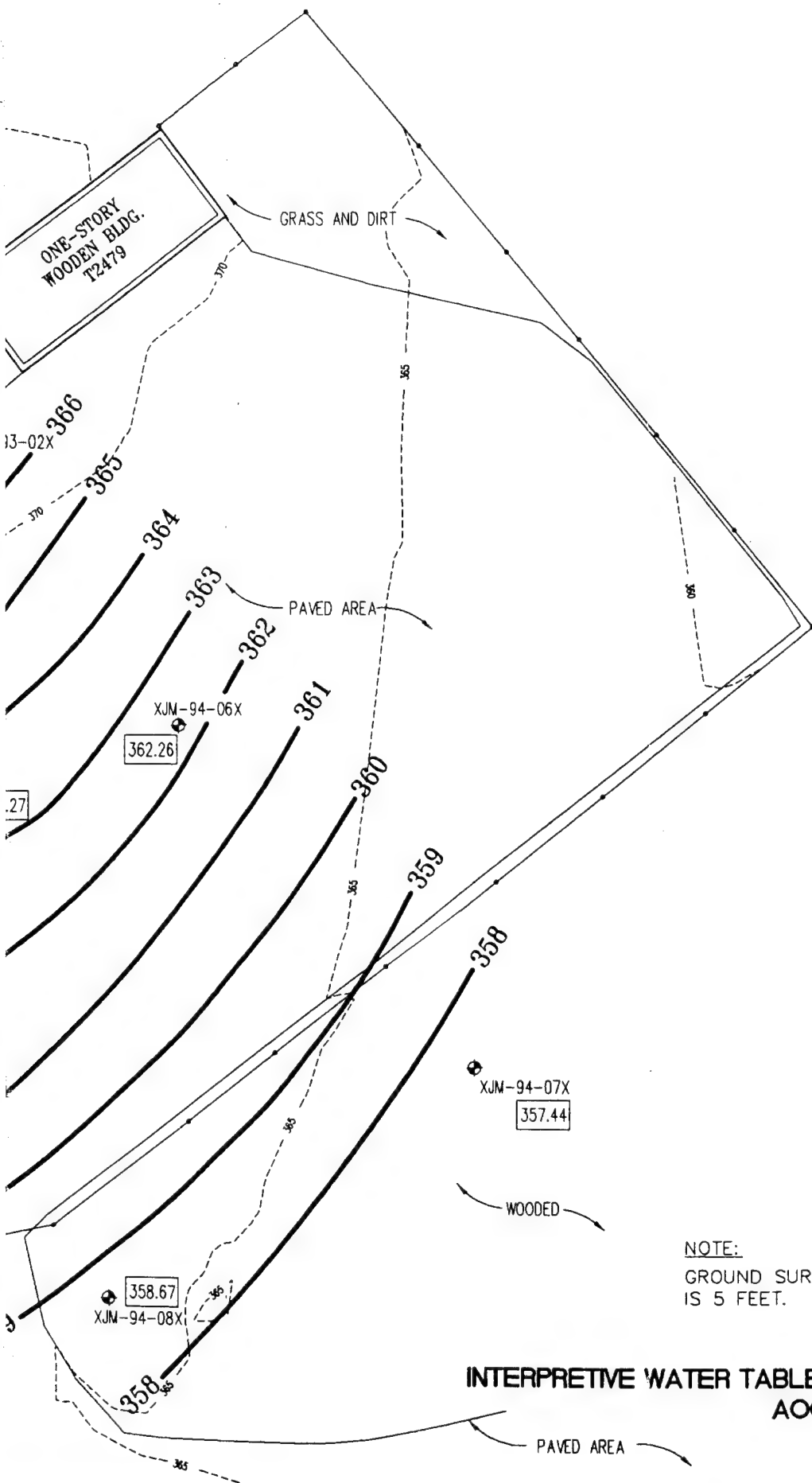
GROUND SURFACE ELEVATION CONTOUR INTERVAL IS 5 FEET.

FIGURE 1-8
INTERPRETIVE WATER TABLE ELEVATION CONTOURS - 1/31/95
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA



0 25 50 100 FEET

SCALE: 1"=50'



LEGEND

- 345 — INTERPRETIVE WATER TABLE ELEVATION CONTOUR
- 361.83 ELEVATION OF GROUNDWATER MAY 9, 1995
- PIEZOMETER
XJP-94-02X
- MONITORING WELL
XJM-94-05X
- CHAIN LINK FENCE WITH BARBED WIRE TOP

NOTE:

GROUND SURFACE ELEVATION CONTOUR INTERVAL IS 5 FEET.

FIGURE 1-9
INTERPRETIVE WATER TABLE ELEVATION CONTOURS-5/9/95
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA

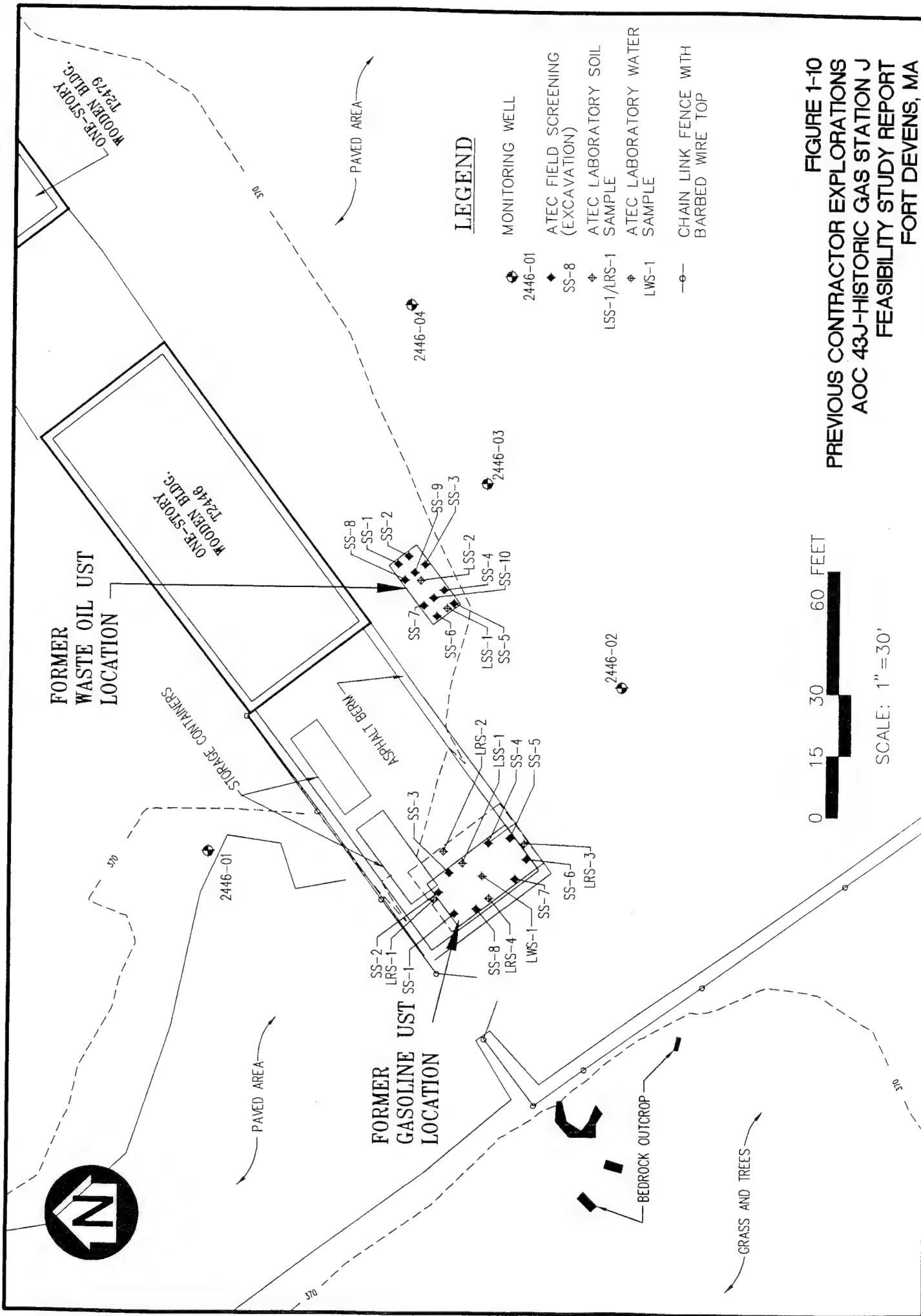
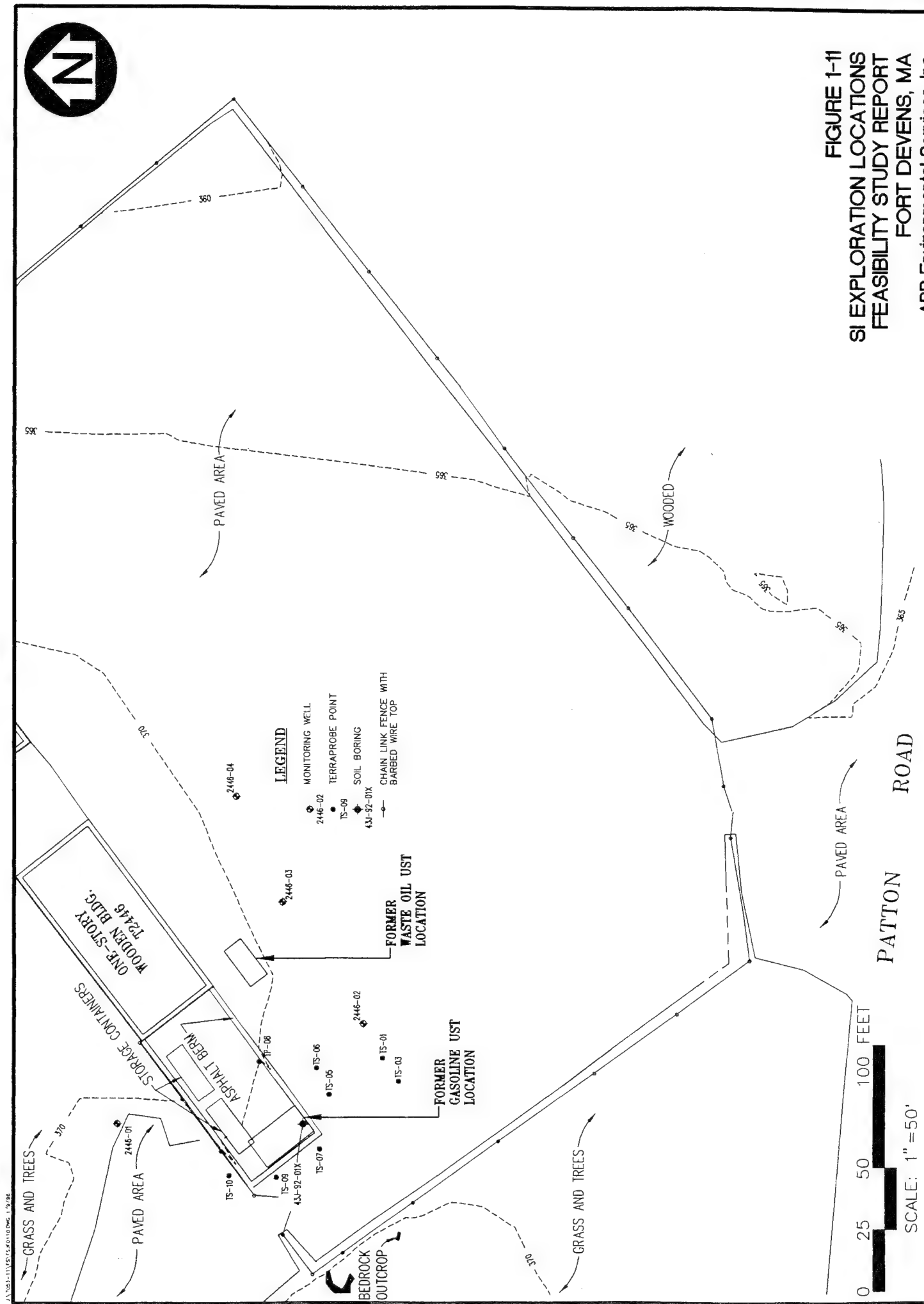


FIGURE 1-11
SI EXPLORATION LOCATIONS
FEASIBILITY STUDY REPORT
FORT DEVENS, MA
ABB Environmental Services, Inc.



LEGEND

MONITORING WELL

2446-03

TERRAPROBE POINT

TS-11

CHAIN LINK FENCE WITH
BARBED WIRE TOP

TS-11

XJM-93-01X

ONE-STORY
WOODEN BLDG.
72446

XJM-93-02X

570

PAVED AREA

PAVED AREA

TS-18

TS-19

TS-24

TS-25

TS-27

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TS-22

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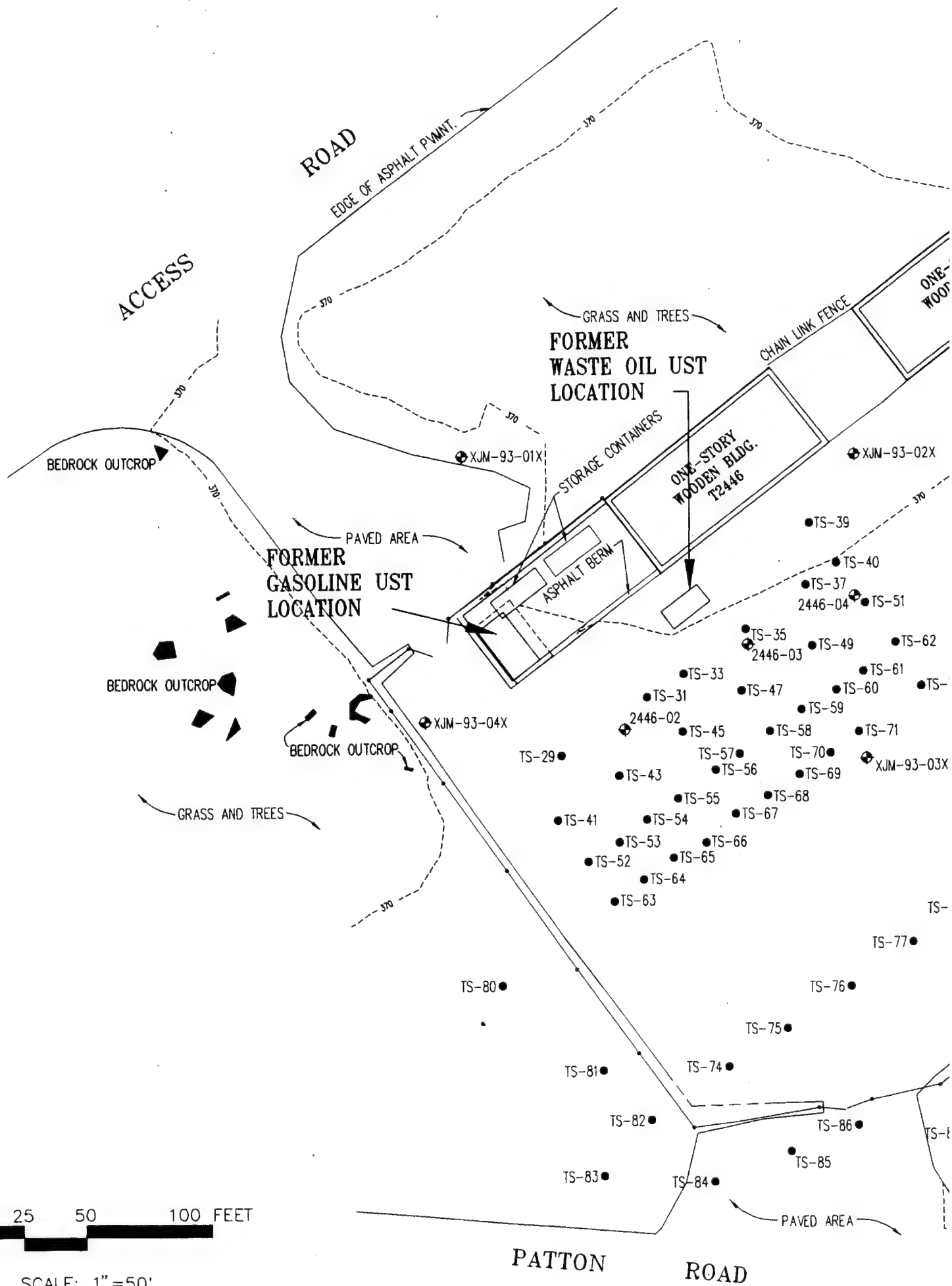
TS-266

TS-267

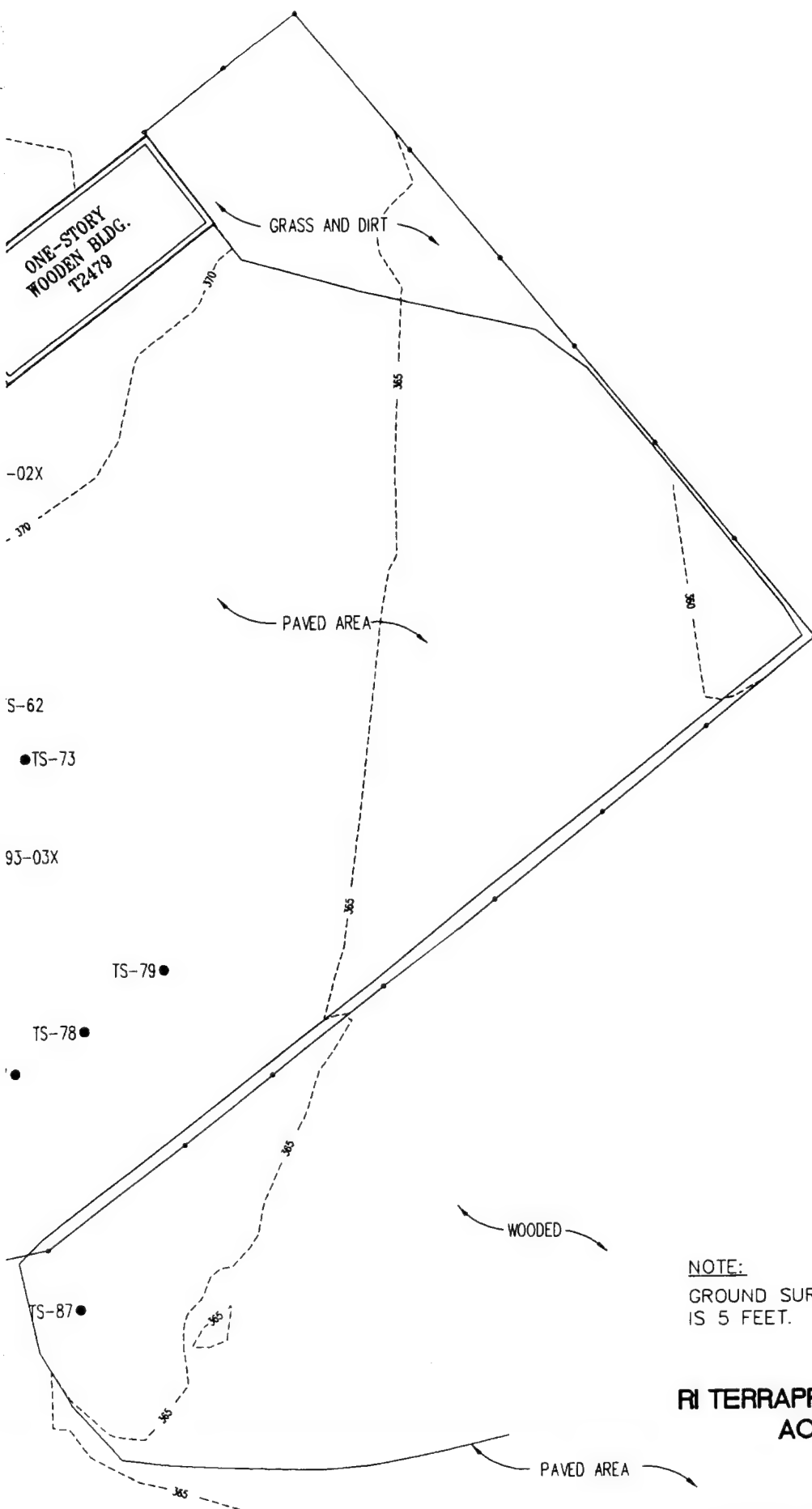
TS-268

TS-269




TS-270



0 25 50 100 FEET



LEGEND

-  MONITORING WELL
-  TERRAPROBE POINT
-  CHAIN LINK FENCE WITH BARBED WIRE TOP

NOTE:

GROUND SURFACE ELEVATION CONTOUR INTERVAL IS 5 FEET.

FIGURE 1-13
RI TERRAPROBE EXPLORATION LOCATIONS
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA

**TABLE 1-1
SUMMARY OF BEDROCK ELEVATION DATA**

**AOC 43J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA**

EXPLORATION TYPE	EXPLORATION ID	GROUND ELEVATION (Feet MSL)	DEPTH TO BEDROCK ¹ (Feet bgs)	BEDROCK ELEVATION (Feet MSL)
BORINGS	43J-92-01X	369.4	6.2	363.2
	XJB-94-02X	367.56	NE	NA
	XJB-94-03X	368.9	17	351.9
	XJB-94-04X	370.3	22.5	347.8
	XJB-94-05X	370.1	18	352.1
	XJB-94-06X	369.7	17.5	352.2
	XJB-94-07X	370.5	21.5	349
	XJB-94-08X	369.2	12.5	356.7
	XJB-94-09X	369.4	20.5	348.9
	XJB-94-10X	368.8	21.5	347.3
	XJB-94-11X	368.4	18.5	349.9
	XJB-94-12X	367.5	14.5	353
	XJB-94-13X	367.1	18.5	348.6
	XJB-94-14X	368	20	348
	XJB-94-15X	366.1	21.5	344.6
	XJB-94-16X	366.8	27.5	339.3
MONITORING WELLS	XJM-93-01X	369.2	13.2	356
	XJM-93-02X	371.1	17.5	353.6
	XJM-93-03X	368.5	NE	NA
	XJM-93-04X	368.7	0.7	368
	XJM-94-05X	368.9	16.1	352.8
	XJM-94-06X	367.9	16	351.9
	XJM-94-07X	362.2	NE	NA
	XJM-94-08X	366.7	NE	NA
	XJM-94-09X	369	22	347
	XJM-94-10X	369	22.5	346.5
	2446-01	369.8	NE	NA
	2446-02	369	NE	NA
	2446-03	369.5	NE	NA
	2446-04	369.6	NE	NA
PIEZOMETERS	XJP-94-01X	368.8	16.5	352.3
	XJP-94-02X	368.5	17.2	351.3
	XJP-94-03X ²	362.5	58.5	304

Notes:

¹ Top of bedrock defined by split-spoon and/or auger refusal.

² A piezometer was not installed in XJP-94-03X.

bgs = below ground surface

MSL = Mean Sea Level

NA = Not Applicable

NE = Not Encountered

TABLE 1-2
SUMMARY OF WATER LEVEL ELEVATION DATA

AOC 43J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA

WELL/ PIEZOMETER ID ¹	REF. POINT	ELEV. OF REF. POINT (FEET/MSL)	OCTOBER 4, 1994		JANUARY 31, 1995		MAY 9, 1995	
			DEPTH TO WATER (FEET)	ELEV. OF WATER (FEET/MSL)	DEPTH TO WATER (FEET)	ELEV. OF WATER (FEET/MSL)	DEPTH TO WATER (FEET)	ELEV. OF WATER (FEET/MSL)
XJM-93-01X	PVC	371.4	7.8	363.6	6.1	365.3	6.6	364.8
XJM-93-02X	PVC	370.63	12.1	358.6	10.1	360.5	3.8	366.8
XJM-93-03X	PVC	368.02	8.6	359.4	6.3	361.7	4.6	363.4
XJM-93-04X	PVC	371.17	8.2	362.9	6.4	364.7	6.3	364.9
XJM-94-05X	PVC	368.51	Not Installed	Not Installed	5.7	362.8	5.3	363.2
XJM-94-06X	PVC	367.36	Not Installed	Not Installed	6.8	360.6	5.1	362.3
XJM-94-07X	PVC	365.04	Not Installed	Not Installed	6.7	358.3	7.6	357.4
XJM-94-08X	PVC	369.27	Not Installed	Not Installed	9.4	359.9	10.6	358.7
XJM-94-09X	PVC	371.58	Not Installed	Not Installed	7.9	363.6	9.3	362.3
XJM-94-10X	PVC	371.39	Not Installed	Not Installed	8.4	363.0	9.5	361.9
2446-02	PVC	368.91	8.3	360.6	Not Measured	Not Measured	4.7	364.2
2446-03	PVC	369.16	9.4	359.8	Not Measured	Not Measured	3.9	365.3
2446-04	PVC	369.38	10.2	359.2	Not Measured	Not Measured	3.9	365.4
XJP-94-01X	PVC	368.51	Not Installed	Not Installed	5.9	362.6	5.2	363.3
XJP-94-02X	PVC	368.27	Not Installed	Not Installed	6.2	362.1	5.6	362.6

Notes:

¹ Monitoring well 2446-01 has been destroyed.

MSL = Mean Sea Level

PVC = Polyvinyl chloride

TABLE 1-3
SUMMARY OF MONITORING WELL AND PIEZOMETER COMPLETION DETAILS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

WELL/PIEZOMETER IDENTIFICATION	SOIL DRILLING METHOD	BEDROCK DRILLING METHOD	MEDIA SCREENED	WELL SCREEN DEPTH (Feet bgs)	WELL SCREEN ELEVATION (Feet MSL)	COMPLETION DEPTH (Feet bgs)	CONSTRUCTION MATERIAL
PREVIOUS CONTRACTOR¹							
2446-01	HOLLOW STEM AUGER	NA	SOIL	5.0-15.0	364.0-354.0	15.0	2" ID PVC
2446-02	HOLLOW STEM AUGER	NA	SOIL	8.0-18.0	361.5-351.5	18.8	2" ID PVC
2446-04	HOLLOW STEM AUGER	NA	SOIL	10.0-20.0	359.6-349.6	20.0	2" ID PVC
SUPPLEMENTARY SITE INVESTIGATION							
XJM-93-01X	HOLLOW STEM AUGER	ROLLER CONE	SOIL/BEDROCK	6.5-16.5	362.7-352.7	17.0	4" ID PVC
XJM-93-02X	HOLLOW STEM AUGER DRIVE AND WASH	NA	SOIL	5.9-15.9	365.2-355.2	17.5	4" ID PVC
XJM-93-03X	HOLLOW STEM AUGER	NA	SOIL	6.6-16.6	361.9-351.9	18.0	4" ID PVC
XJM-93-04X	NA	ROCK CORE/OVER REAM	BEDROCK	4.5-14.5	364.2-354.2	15.2	4" ID PVC
REMEDIAL INVESTIGATION							
XJM-94-05X	HOLLOW STEM AUGER DRIVE AND WASH	NA	SOIL	6.1-16.1	362.8-352.8	16.1	4" ID PVC
XJM-94-06X	HOLLOW STEM AUGER DRIVE AND WASH	ROLLER CONE	SOIL/BEDROCK	6.7-16.7	361.2-351.2	17.0	4" ID PVC
XJM-94-07X	HOLLOW STEM AUGER DRIVE AND WASH	ROCK CORE/OVER REAM	SOIL/BOULDER	3.7-13.7	358.5-348.5	16.4	4" ID PVC
XJM-94-08X	HOLLOW STEM AUGER	NA	SOIL	7.6-17.6	359.1-349.1	18.0	4" ID PVC
XJM-94-09X	HOLLOW STEM AUGER DRIVE AND WASH	NA	SOIL	8.7-18.7	360.3-350.3	22.0	4" ID PVC
XJM-94-10X	HOLLOW STEM AUGER DRIVE AND WASH	NA	SOIL	7.8-17.8	361.2-351.2	22.5	4" ID PVC
XJP-94-01X	HOLLOW STEM AUGER	NA	SOIL	6.2-16.2	362.6-352.6	16.5	1.5" ID PVC
XJP-94-02X	HOLLOW STEM AUGER	NA	SOIL	7.2-17.2	361.3-351.3	17.2	1.5" ID PVC

Notes:

¹ Monitoring well 2446-01 has been destroyed.

bgs = below ground surface

ID = Inside Diameter

MSL = Mean Sea Level

NA = Not Applicable

PVC = Polyvinyl Chloride

Drive and Wash =

Boring advanced to refusal with hollow stem auger. 6-inch ID casing is then driven to or beyond refusal depth.

Boring is cleaned out with 5 7/8-inch OD roller cone and advanced into bedrock if so noted.

Boring was advanced through bedrock by first coring with HQ 4-inch OD core barrel and then reaming out bedrock borehole with 5 7/8-inch OD roller cone to desired depth for installation of 4-inch ID monitoring well.

TABLE 1-4
SUMMARY OF ANALYTICAL PROGRAM
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

FIELD EVENT	MATRIX	SAMPLE TYPE	EXPLORATION ID	DEPTH	ROUND	PARAMETERS										FIELD ANALYTICAL		
						OFF-SITE LABORATORY - PAL ANALYSIS				LABORATORY - PAL ANALYSIS						BTX	CHLOR	TPHC/IR
						VOC	SVOC	INOR - tot	INOR - dist	TCLP Metals	TPHC	H2O QUAL	TSS	TOC				
Waste Oil UST Removal	Soil	Excavation	SS-1															X
			SS-2															X
			SS-3															X
			SS-4															X
			SS-5															X
			SS-6															X
			SS-7															X
			SS-8															X
			SS-9															X
			SS-10															X
Historic Gas Station Gasoline UST Removal	Soil	Excavation	LSS-1								X							X
			LSS-2								X							X
			SS-1															X
			SS-2															X
			SS-3															X
			SS-4															X
			SS-5															X
			SS-6															X
			SS-7															X
			SS-8															X
SI	Water	Excavation	LSS-1															X
			LSS-2															X
			LRS-1															X
			LRS-2															X
			LRS-3															X
			LRS-4															X
			LSS-1															X
			LWS-1															X
			43J-92-01X															X
			TS-01	5-7		X		X*								X		X
	Soil	T_Probe	TS-03	8-9												X		X
			TS-05	8-9												X		X
			TS-06	3-4												X		X
			TS-07	8-9												X		X
			TS-08	3-4												X		X
			TS-09	8-9												X		X
			TS-10	3-4												X		X
				3-4												X		X
																X		X
																X		X

TABLE 1-4
SUMMARY OF ANALYTICAL PROGRAM
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

FIELD EVENT	MATRIX	SAMPLE TYPE	EXPLORATION ID	DEPTH	ROUND	PARAMETERS											
						OFF-SITE LABORATORY - PAL ANALYSES						FIELD ANALYTICAL					
						VOC	SVOC	INOR - tot	INOR - diss	TCLP Metals	TPHC	H2O QUAL	TSS	TOC	BTEX	CHLOR	TPHC/IR
SSI	Soil	T_Probe	TS-11	8-9											X		X
			TS-12	8-9											X		X
			TS-13	8-9											X		X
			TS-14	8-9											X		X
			TS-16	8-9											X		X
			TS-17	8-9											X		X
			TS-17	9-11											X		X
			TS-18	8-9											X		X
			TS-19	8-9											X		X
			TS-20	8-9											X		X
			TS-22	8-9											X		X
			TS-23	8-9											X		X
			TS-24	8-9											X		X
			TS-25	8-9											X		X
			TS-26	8-9											X		X
			TS-27	8-9											X		X
	Water	Groundwater	2446-02		3	X	X										
			2446-02		4	X	X	X	X				X	X			
			2446-03		3	X	X	X	X				X	X			
			2446-03		4	X	X	X	X				X	X			
			2446-04		3	X	X	X	X				X	X			
	Water	Groundwater	2446-04		4	X	X	X	X				X	X			
			XJM-93-01X	10-12													
			XJM-93-02X	5-7													
			XJM-93-02X	10-12													
			XJM-93-03X	15-17													
			XJM-93-01X		3	X	X										
			XJM-93-01X		4	X	X	X	X				X	X			
			XJM-93-02X		3	X	X	X	X				X	X			
			XJM-93-02X		4	X	X	X	X				X	X			
			XJM-93-03X		3	X	X	X	X				X	X			
	Water	Groundwater	XJM-93-03X		4	X	X	X	X				X	X			
			XJM-93-04X		3	X	X	X	X				X	X			
			XJM-93-04X		4	X	X	X	X				X	X			

TABLE 1-4
SUMMARY OF ANALYTICAL PROGRAM
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

FIELD EVENT	MATRIX	SAMPLE TYPE	EXPLORATION ID	DEPTH	ROUND	PARAMETERS											FIELD ANALYTICAL		
						OFF-SITE LABORATORY - PAL ANALYSES											BTX	CHLOR	TPHC/IR
						VOC	SVOC	INOR-tot	INOR-diss	TCLP Metals	TPHC	H2O QUAL	TSS	TOC					
RI	Water	S_Auger	SAJ01	13-23													X	X	X
			SAJ02	15-25													X	X	X
			SAJ03	13-23													X	X	X
			SAJ04	11-21													X	X	X
			SAJ05	12-22													X	X	X
			SAJ06	13-23													X	X	X
			SAJ07	8-18													X	X	X
			SAJ08	7-17													X	X	X
			SAJ09	9-19													X	X	X
			SAJ10	13-23													X	X	X
	Soil	T_Probe	TS-31	7-9													X	X	X
			TS-31	9-11													X	X	X
			TS-33	7-9													X	X	X
			TS-33	9-11													X	X	X
			TS-35	7-9													X	X	X
			TS-37	7-9													X	X	X
			TS-37	9-11													X	X	X
			TS-39	7-9													X	X	X
			TS-39	9-11													X	X	X
			TS-40	7-9													X	X	X
			TS-40	9-11													X	X	X
			TS-41	7-9													X	X	X
			TS-43	7-9													X	X	X
			TS-43	9-11													X	X	X
			TS-45	7-9													X*	X*	X*
			TS-45	9-11													X	X	X
			TS-47	7-9													X	X	X
			TS-47	9-11													X	X	X
			TS-49	7-9													X	X	X
			TS-51	7-9													X	X	X
			TS-51	9-11													X	X	X
			TS-52	7-9													X	X	X
			TS-52	9-11													X	X	X

TABLE 1-4
SUMMARY OF ANALYTICAL PROGRAM
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

FIELD EVENT	MATRIX	SAMPLE TYPE	EXPLORATION ID	DEPTH	ROUND	PARAMETERS													FIELD ANALYTICAL	
						OFF-SITE LABORATORY - PAL ANALYSES														
						VOC	SVOC	INOR--1st	INOR--dist	TCLP Metals	TPHC	H2O QUAL	TSS	TOC	BTEX	CHLOR	TPHC/IR			
RI (cont.)	Soil	T_Probe	TS-53	7-9													X	X		
			TS-53	9-11														X	X	
			TS-54	7-9															X	X
			TS-54	9-11															X	X
			TS-55	7-9															X	X
			TS-55	9-11															X	X
			TS-56	7-9															X	X
			TS-56	9-11															X	X
			TS-57	7-9															X	X
			TS-57	9-11															X	X
			TS-58	7-9															X	X
			TS-58	9-11															X	X
			TS-59	7-9															X	X
			TS-59	9-11															X	X
			TS-60	7-9															X	X
			TS-60	9-11															X	X
			TS-61	7-9															X	X
			TS-61	9-11															X	X
			TS-62	7-9															X	X
			TS-63	7-9															X	X
			TS-63	9-11															X	X
TS-64	7-9															X	X			
TS-64	9-11															X	X			
TS-65	7-9															X	X			
TS-66	7-9															X	X			
TS-66	9-11															X	X			
TS-67	7-9															X	X			
TS-67	9-11															X	X			
TS-68	7-9															X	X			
TS-68	9-11															X	X			
TS-69	7-9															X	X			
TS-69	9-11															X	X			
TS-70	7-9															X	X			
TS-70	9-11															X	X			
TS-71	7-9															X	X			

TABLE 1-4
SUMMARY OF ANALYTICAL PROGRAM
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

FIELD EVENT	MATRIX	SAMPLE TYPE	EXPLORATION ID	DEPTH	ROUND	PARAMETERS											FIELD ANALYTICAL		
						OFF-SITE LABORATORY - PAL ANALYSES													
						VOC	SVOC	INOR - 1st	INOR - 2nd	TCLP Metals	TPHC	H2O QUAL	TSS	TOC	BTEX	CHLOR	TPHC/IR		
			TS-73	7-9													X	X	X
			TS-73	9-11													X	X	X
			TS-74	7-9													X	X	X
			TS-74	9-11													X	X	X
			TS-74	9-11													X	X	X
			TS-75	7-9													X	X	X
			TS-75	9-11													X	X	X
			TS-76	7-9													X	X	X
			TS-76	9-11													X	X	X
			TS-76	9-11													X	X	X
			TS-77	7-9													X	X	X
			TS-77	9-11													X	X	X
			TS-78	7-9													X	X	X
			TS-78	9-11													X	X	X
			TS-79	7-9													X	X	X
			TS-79	9-11													X	X	X
			TS-81	5-7													X	X	X
			TS-82	7-9													X	X	X
			TS-82	9-11													X	X	X
			TS-83	7-9													X	X	X
			TS-83	9-11													X	X	X
			TS-84	7-9													X	X	X
			TS-84	9-11													X	X	X
			TS-84	9-11													X	X	X
			TS-85	7-9													X	X	X
			TS-85	9-11													X	X	X
			TS-85	9-11													X	X	X
			TS-86	7-9													X	X	X
			TS-86	9-11													X	X	X
			TS-86	9-11													X	X	X
			TS-87	7-9													X	X	X
			TS-87	9-11													X	X	X
			XJB-94-02X	5-7		X	X	X	X								X	X	X
			XJB-94-02X	7-9		X	X	X	X								X	X	X
			XJB-94-02X	9-11													X	X	X

TABLE 1-4
SUMMARY OF ANALYTICAL PROGRAM
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

FIELD EVENT	MATRIX	SAMPLE TYPE	EXPLORATION ID	DEPTH	ROUND	PARAMETERS										FIELD ANALYTICAL				
						OFF-SITE LABORATORY - PAL ANALYSES										BTX	CHLOR	TPHC/IR		
						VOC	SVOC	INOR - tot	INOR - diss	TCLP Metals	TPHC	H2O QUAL	TSS	TOC						
RI (cont.)	Soil	Boring	XJB-94-03X	5-7												X	X	X		
			XJB-94-03X	7-9													X	X	X	
			XJB-94-03X	9-11													X	X	X	
			XJB-94-03X	11-13																
			XJB-94-03X	15-17																
			XJB-94-04X	1-3																
			XJB-94-04X	10-12																
			XJB-94-04X	15-17																
			XJB-94-04X	20-22																
			XJB-94-05X	1-3																
			XJB-94-05X	3-5																
			XJB-94-05X	5-7																
			XJB-94-05X	7-9																
			XJB-94-05X	9-11																
			XJB-94-05X	11-13																
			XJB-94-05X	13-15																
			XJB-94-05X	15-17																
			XJB-94-05X	17-19																
			XJB-94-06X	5-7																
			XJB-94-06X	10-12																
			XJB-94-06X	12-14																
			XJB-94-06X	15-17																
			XJB-94-07X	7-9																
			XJB-94-07X	9-11																
			XJB-94-07X	11-13																
			XJB-94-07X	15-17																
			XJB-94-08X	7-9																
			XJB-94-08X	9-11																
			XJB-94-08X	11-13																
			XJB-94-09X	7-9																
			XJB-94-09X	9-11																
			XJB-94-09X	11-13																
			XJB-94-10X	7-9																
			XJB-94-10X	9-11																
			XJB-94-10X	11-13																

TABLE 1-4
SUMMARY OF ANALYTICAL PROGRAM
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

FIELD EVENT	MATRIX	SAMPLE TYPE	EXPLORATION ID	DEPTH	ROUND	PARAMETERS									
						OFF-SITE LABORATORY - PAL ANALYSES					FIELD ANALYTICAL				
						VOC	SVOC	INOR-tot	INOR-dis	TCLP Metals	TPHC	H2O QUAL	TSS	TOC	BTX CHLOR TPHC/IR
RI (cont.)	Soil	Boring	XJB-94-10X	15-17		X									X
			XJB-94-10X	20-22		X	X	X			X				X
			XJB-94-11X	7-9		X	X	X			X				X
			XJB-94-11X	9-11											X
			XJB-94-11X	11-13		X	X	X			X				X
			XJB-94-11X	15-17		X					X				X
			XJB-94-12X	7-9		X	X	X			X				X
			XJB-94-12X	9-11		X					X				X
			XJB-94-12X	11-13		X	X	X			X				X
			XJB-94-13X	7-9		X	X	X			X				X
	Soil	Boring	XJB-94-13X	9-11		X	X	X			X				X
			XJB-94-13X	11-13		X	X	X			X				X
			XJB-94-13X	15-17		X					X				X
			XJB-94-14X	7-9											X
			XJB-94-14X	9-11											X
			XJB-94-14X	11-13		X	X	X			X				X
			XJB-94-14X	15-17		X	X	X			X				X
			XJB-94-15X	7-9		X	X	X			X				X
			XJB-94-15X	9-11		X	X	X			X				X
			XJB-94-15X	11-13		X	X	X			X				X
	Soil	Boring	XJB-94-15X	15-17		X	X	X			X				X
			XJB-94-16X	7-9		X	X	X			X				X
			XJB-94-16X	20-22		X	X	X			X				X
			XJM-94-05X	10-12										X	
			XJM-94-06X	10-12										X	
	Water	Groundwater	XJM-94-08X	15-17											
			XJM-94-10X	15-17											
			2446-02		5	X	X	X							
			2446-02		6	X	X	X							
			2446-03		5	X	X	X							
			2446-03		6	X	X	X							
			2446-04		5	X	X	X							
			2446-04		6	X	X	X							
			XJM-93-01X		5	X	X	X							
			XJM-93-01X		6	X	X	X							

TABLE 1-4
SUMMARY OF ANALYTICAL PROGRAM
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

FIELD EVENT	MATRIX	SAMPLE TYPE	EXPLORATION ID	DEPTH	ROUND	PARAMETERS										FIELD ANALYTICAL	
						OFF-SITE LABORATORY - PAL ANALYSES					PAL ANALYSES					BTEX	CHLOR TPHC/IR
RI (cont.)	Water	Groundwater				VOC	SVOC	INOR-tot	INOR-dis	TCLP Metals	TPHC	H2O QUAL	TSS	TOC			
						5	X	X	X			X	X				
						6	X	X	X			X	X				
						5	X	X	X			X	X				
						6	X	X	X			X	X				
						5	X	X	X			X	X				
						6	X	X	X			X	X				
						5	X	X	X			X	X				
						6	X	X	X			X	X				
						5	X	X	X			X	X				
						6	X	X	X			X	X				
						5	X	X	X			X	X				
						6	X	X	X			X	X				
						5	X	X	X			X	X				
						6	X	X	X			X	X				
						5	X	X	X			X	X				
						6	X	X	X			X	X				

Notes:

VOA = Volatile Organic Analysis

SVOC = Semivolatile Organic Analysis

P/P = Pesticide/PCBs

Inorg. = Inorganics

TOC = Total Organic Carbon

EX = Explosives

TSS = Total Suspended Solids

tot = unfiltered

dis = filtered

CHLOR = Chlorinated VOCs (Select list developed for a concurrent sampling program at AOC 41 consisting of vinyl chloride, t- and c-1,2-dichloroethene, trichloroethene, tetrachloroethene, 1-2-dichlorobenzene and 1,1,2,2-tetrachloroethane).

TDS = Total Dissolved Solids

TPHC = Total Petroleum Hydrocarbons

H2O QUAL = Sulfate, Alkalinity, Phosphate, Nitrite as Nitrogen, Total Kjeldhal Nitrogen

BTEX = Benzene, Toluene, ethylbenzene, M/P/O-Xylenes

PAL = Project Analyte List (See Appendix K of the RI Report for a list of these analytes).

TPHC/IR = Total Petroleum Hydrocarbons by Infrared Spectrophotometry

X* = Chlorinated VOCs without Vinyl Chloride

* = Lead only

TCLP = Toxic Compound Leaching Procedure

**TABLE 1-5
CHEMICALS OF POTENTIAL CONCERN
AOC 43J**

**FEASIBILITY STUDY REPORT
FORT DEVENS, MA**

Range of SOLs	Frequency of Detection	Detected Concentrations		Mean of all Samples	Back- Ground	CPC?	Notes
		Minimum	Maximum				
SOURCE AREA SUBSURFACE SOIL (1 - 15 feet bgs) ^a (mg/kg)							
PAL METALS							
Aluminum	N/A	9/9	3950	9500	7145.6	18000	No Background ¹
Antimony	1.09 - 1.09	2/9	2.01	3.28	1.0	0.5	Yes
Arsenic	N/A	9/9	9.4	20	14.1	19	Yes
Barium	N/A	9/9	15.3	28.7	20.1	54	No Background ¹
Calcium	N/A	9/9	566	1450	963.2	810	No Essential Nutrient ²
Chromium	N/A	9/9	12.9	36	18.7	33	Yes
Cobalt	1.42 - 1.42	9/9	5.99	9.84	7.7	4.7	Yes
Copper	N/A	9/9	14.5	169	33.3	13.5	Yes
Iron	N/A	9/9	12900	18000	15877.8	18000	No Background ¹
Lead	N/A	10/10	6.7	86	18.0	48	Yes Toxicity Value ³
Magnesium	N/A	9/9	1680	4120	3536.7	5500	No Background ¹ , Essential Nutri ²
Manganese	N/A	9/9	252	828	489.9	380	Yes
Nickel	N/A	9/9	23.2	36.9	29.5	14.6	Yes
Potassium	N/A	9/9	561	1180	769.1	2400	No Background ¹ , Essential Nutri ²
Sodium	N/A	9/9	366	485	431.2	234	No Essential Nutrient ²
Vanadium	N/A	9/9	6.42	20.6	10.8	32.3	No Background ¹
Zinc	N/A	9/9	21.7	99	40.4	43.9	Yes
PAL SEMIVOLATILE ORGANICS							
2-Methylnaphthalene	0.049 - 0.5	6/9	0.093	7	1.3	NDB	Yes
bis(2-Ethylhexyl)phthalate	0.62 - 6	2/9	1	2.8	1.1	NDB	No Blank ⁴
Di-n-butyl Phthalate	0.061 - 0.6	1/9	1.4	1.4	0.2	NDB	No Blank ⁴
Naphthalene	0.037 - 0.4	5/9	0.71	10	1.5	NDB	Yes
Phenanthrene	0.033 - 0.2	1/9	0.5	0.5	0.08	NDB	Yes
Pyrene	0.033 - 0.2	1/9	0.7	0.7	0.1	NDB	Yes
PAL VOLATILE ORGANICS							
Xylenes	0.002 - 0.002	8/10	0.0063	100	30	NDB	Yes
Acetone	0.017 - 8	1/10	0.044	0.044	0.9	NDB	No Blank ⁴
Chloroform	0.001 - 0.4	1/10	0.0081	0.0081	0.04	NDB	No Blank ⁴
Ethylbenzene	0.002 - 0.002	7/10	0.0042	30	7.8	NDB	Yes
Toluene	0.001 - 0.001	5/10	0.1	20	3.6	NDB	Yes
Trichlorofluoromethane	0.006 - 3	1/10	0.0082	0.0082	0.3	NDB	No Blank ⁴
OTHER							
Total Petroleum Hydrocarbons	NA	10/10	46.2	1880	519.2	NDB	Yes Toxicity Value ³
PERIMETER AREA SUBSURFACE SOIL (1 - 15 feet bgs) ^b (mg/kg)							
PAL METALS							
Aluminum	N/A	15/15	2800	13900	6932	18000	No Background ¹
Antimony	1.09 - 1.09	1/15	2.21	2.21	0.7	0.5	Yes
Arsenic	N/A	15/15	8.06	31	16.9	19	Yes
Barium	N/A	15/15	6.56	49	19.8	54	No Background ¹
Beryllium	0.5 - 0.5	1/15	0.723	0.723	0.3	0.81	No Background ¹
Cadmium	0.7 - 0.7	1/15	1.1	1.1	0.4	1.28	No Background ¹
Calcium	N/A	15/15	321	3920	1022.9	810	No Essential Nutrient ²
Chromium	N/A	15/15	6.67	55.4	19.6	33	Yes
Cobalt	1.42 - 1.42	14/15	3.83	14.8	7.5	4.7	Yes
Copper	N/A	15/15	4.49	38.6	16.8	13.5	Yes
Iron	N/A	15/15	3540	26000	15577.3	18000	Yes
Lead	N/A	15/15	3.18	54	10.7	48	Yes Toxicity Value ³
Magnesium	N/A	15/15	1070	8220	3587.3	5500	No Essential Nutrient ²
Manganese	N/A	15/15	62.8	890	384.3	380	Yes
Nickel	N/A	15/15	5.3	50.2	29.09	14.6	Yes
Potassium	N/A	15/15	234	2940	875.7	2400	No Essential Nutrient ²
Sodium	N/A	15/15	311	452	403.1	234	No Essential Nutrient ²
Vanadium	N/A	15/15	5.14	31.4	11.4	32.3	No Background ¹
Zinc	N/A	15/15	10.1	70.4	33.9	43.9	Yes
PAL SEMIVOLATILE ORGANICS							
bis(2-Ethylhexyl)phthalate	0.62 - 3	2/15	0.76	8.1	1.0	NDB	No Blank ⁴
Di-n-butylphthalate	0.061 - 0.3	3/15	0.12	1.3	0.1	NDB	No Blank ⁴
PAL VOLATILE ORGANICS							
Acetone	0.017 - 0.017	1/15	0.062	0.062	0.01	NDB	No Blank ⁴
Trichlorofluoromethane	0.006 - 0.006	9/15	0.0057	0.018	0.008	NDB	No Blank ⁴
OTHER							
Total Petroleum Hydrocarbons	21.1 - 28.8	9/15	34.5	566	116.4	NDB	Yes Toxicity Value ³

**TABLE 1-5
CHEMICALS OF POTENTIAL CONCERN
AOC 43J**

**FEASIBILITY STUDY REPORT
FORT DEVENS, MA**

	Range of SOLs	Frequency of Detection	Detected Concentrations		Mean of all Samples	Back- Ground	CPC?	Notes
			Minimum	Maximum				
SOURCE AREA GROUNDWATER _c (mg/L) - UNFILTERED								
PAL METALS								
Aluminum	0.141 - 0.141	11/12	0.285	21	5.7	6.87	Yes	
Arsenic	NA	12/12	0.00373	0.0878	0.04	0.0105	Yes	
Barium	NA	12/12	0.0087	0.119	0.1	0.0396	Yes	
Cadmium	0.004 - 0.004	1/12	0.00579	0.00579	0.002	0.00401	Yes	
Calcium	NA	12/12	40.7	87.7	54.3	14.7	No	Essential Nutrient ₂
Chromium	0.006 - 0.006	7/12	0.00886	0.0351	0.01	0.0147	Yes	
Cobalt	0.025 - 0.025	1/12	0.0306	0.0306	0.01	0.025	Yes	
Copper	0.008 - 0.008	5/12	0.0136	0.0325	0.01	0.00809	Yes	
Iron	NA	12/12	8.07	49.7	21.0	9.1	Yes	
Lead	0.001 - 0.001	12/12	0.00126	0.0267	0.008	0.00425	Yes	
Magnesium	NA	12/12	7.67	18.2	12.6	3.48	No	Essential Nutrient ₂
Manganese	NA	12/12	1.65	18.2	9.6	0.291	Yes	
Nickel	0.034 - 0.034	2/12	0.0577	0.0626	0.02	0.0343	Yes	
Potassium	NA	12/12	1.82	74.6	3.7	2.37	No	Essential Nutrient ₂
Sodium	NA	12/12	18.2	68.9	47.2	10.8	No	Essential Nutrient ₂
Vanadium	0.011 - 0.011	3/12	0.015	0.0276	0.009	0.011	Yes	
Zinc	0.021 - 0.021	6/12	0.0293	0.62	0.1	0.0211	Yes	
PAL SEMIVOLATILE ORGANICS								
1,2-Dichlorobenzene	0.002 - 0.002	3/12	0.0048	0.014	0.003	NDB	Yes	
1,4-Dichlorobenzene	0.002 - 0.002	1/12	0.0036	0.0036	0.001	NDB	Yes	
2,4-Dimethylphenol	0.006 - 0.006	1/12	0.0088	0.0088	0.003	NDB	Yes	
2-Methylnaphthalene	0.002 - 0.002	9/12	0.0062	0.1	0.03	NDB	Yes	
2-Methylphenol	0.004 - 0.004	2/12	0.0041	0.0053	0.002	NDB	Yes	
4-Methylphenol	0.001 - 0.001	4/12	0.002	0.011	0.002	NDB	Yes	
Bis(2-Ethylhexyl)phthalate	0.005 - 0.1	9/12	0.0061	0.05	0.02	NDB	No	Blank ₄
Naphthalene	0.001 - 0.001	12/12	0.0041	0.3	0.1	NDB	Yes	
PAL VOLATILE ORGANICS (mg/L)								
Benzene	0.05 - 0.06	10/12	0.0015	0.3	0.10	NDB	Yes	
Ethylbenzene	0.001 - 0.001	10/12	0.14	3	1.3	NDB	Yes	
Toluene	NA	12/12	0.0053	7	1.5	NDB	Yes	
Xylenes	NA	12/12	0.008	8	2.6	NDB	Yes	
Carbon Tetrachloride	0.001 - 0.08	3/12	0.02	0.1	0.02	NDB	Yes	
Chloroform	0.001 - 0.06	5/12	0.001	0.4	0.06	NDB	No	Blank ₄
Methylene Chloride	0.002 - 0.3	6/12	0.0034	0.7	0.1	NDB	No	Blank ₄
SOURCE AREA GROUNDWATER _c (mg/L) - FILTERED								
PAL METALS								
Antimony	0.003 - 0.003	1/12	0.00375	0.00375	0.002	0.00303	Yes	
Arsenic	NA	12/12	0.00362	0.0726	0.03	0.0105	Yes	
Barium	NA	12/12	0.00907	0.0298	0.02	0.0396	No	Background ₁
Calcium	NA	12/12	42.4	61	53.8	14.7	No	Essential Nutrient ₂
Copper	0.008 - 0.008	1/12	0.0133	0.0133	0.004	0.00809	Yes	
Iron	NA	12/12	0.391	30	10.5	9.1	Yes	
Lead	0.001 - 0.001	5/12	0.00141	0.00618	0.002	0.00425	Yes	
Magnesium	NA	12/12	6.57	15.6	11	3.48	No	Essential Nutrient ₂
Manganese	NA	12/12	3.28	18.4	9.6	0.291	Yes	
Potassium	NA	12/12	1.48	3.38	2.5	2.37	No	Essential Nutrient ₂
Sodium	NA	12/12	20.2	67.7	48	10.8	No	Essential Nutrient ₂

**TABLE 1-5
CHEMICALS OF POTENTIAL CONCERN
AOC 43J**

**FEASIBILITY STUDY REPORT
FORT DEVENS, MA**

	Range of SQLs	Frequency of Detection	Detected Concentrations		Mean of all Samples	Back- Ground	CPC?	Notes
			Minimum	Maximum				
DOWNGRADIENT GROUNDWATER _d (mg/L) - UNFILTERED								
PAL METALS								
Aluminum	0.141 - 0.141	8/8	0.171	13.9	2.5	6.87	Yes	
Arsenic	0.003 - 0.003	5/8	0.00277	0.0114	0.004	0.0105	Yes	
Barium	0.005 - 0.005	8/8	0.00806	0.0991	0.03	0.0396	Yes	
Calcium	NA	8/8	7.55	48.3	32.2	14.7	No	Essential Nutrient ₂
Chromium	0.006 - 0.006	2/8	0.0104	0.0392	0.008	0.0147	Yes	
Copper	0.008 - 0.008	1/8	0.015	0.015	0.005	0.00809	Yes	
Iron	NA	8/8	0.0878	22.5	4.7	9.1	Yes	
Lead	0.001 - 0.001	4/8	0.00184	0.0144	0.004	0.00425	Yes	
Magnesium	NA	8/8	1.11	23.7	11.5	3.48	No	Essential Nutrient ₂
Manganese	NA	8/8	0.0272	2.33	0.8	0.291	Yes	
Nickel	0.034 - 0.034	1/8	0.0559	0.0559	0.02	0.0343	Yes	
Potassium	NA	8/8	0.509	6.74	3.4	2.37	No	Essential Nutrient ₂
Sodium	NA	8/8	6.3	19.2	11.5	10.8	No	Essential Nutrient ₂
Vanadium	0.011 - 0.011	1/8	0.016	0.016	0.007	0.011	Yes	
Zinc	0.021 - 0.021	1/8	0.0506	0.0506	0.02	0.0211	Yes	
PAL SEMIVOLATILES								
bis(2-Ethylhexyl)phthalate	0.005 - 0.005	4/8	0.0048	0.041	0.009	NDB	No	Blank ₄
Naphthalene	0.001 - 0.001	1/8	0.0065	0.0065	0.001	NDB	Yes	
PAL VOLATILE ORGANICS								
Benzene	0.001 - 0.001	2/9	0.00056	0.02	0.003	NDB	Yes	
Ethylbenzene	0.001 - 0.001	2/8	0.00092	0.042	0.006	NDB	Yes	
Toluene	0.001 - 0.001	3/8	0.00073	0.042	0.006	NDB	Yes	
Xylenes	0.001 - 0.001	2/8	0.0018	0.089	0.01	NDB	Yes	
Carbon Tetrachloride	0.001 - 0.001	1/8	0.0033	0.0033	0.0007	NDB	Yes	
Chloroform	0.001 - 0.001	2/8	0.00086	0.0052	0.0009	NDB	No	Blank ₄
Methylene Chloride	0.002 - 0.002	1/8	0.0037	0.0037	0.001	NDB	No	Blank ₄
DOWNGRADIENT GROUNDWATER _d (mg/L) - FILTERED								
PAL METALS								
Antimony	0.003 - 0.003	1/8	0.00491	0.00491	0.002	0.00303	Yes	
Arsenic	0.003 - 0.003	1/8	0.00373	0.00373	0.002	0.0105	No	Background ₁
Barium	0.005 - 0.005	6/8	0.00519	0.0219	0.01	0.0396	No	Background ₁
Calcium	NA	8/8	9.24	60.5	32.7	14.7	No	Essential Nutrient ₂
Iron	0.039 - 0.039	1/8	0.0483	0.0483	0.02	9.1	No	Background ₁
Magnesium	NA	8/8	1.49	22.6	11.2	3.48	No	Essential Nutrient ₂
Manganese	NA	8/8	0.00681	2.75	0.8	0.291	Yes	
Potassium	0.375 - 0.375	6/8	0.537	5.74	2.3	2.37	No	Essential Nutrient ₂
Sodium	NA	8/8	5.79	17.9	11.0	10.8	No	Essential Nutrient ₂

NOTES:

- a Based on samples 43J-92-01X, XJB-94-03X, -06X, -08X, -10X, -11X, -12X
b Based on samples XJM-93-01X and -02X, XJB-94-02X, -05X, -07X, -09X, -13X through -16X
c Based on samples XJM-94-05X, XJM-93-02X, -03X, 2446-02 to -04
d Based on samples XJM-94-07X to -10X

SQL - Sample Quantitation Limit
NDB - not detected in background
N/A - not applicable
mg - milligram
kg - kilogram
L - liter
CPC - chemical of potential concern
bgs - below ground surface

Background¹ - Sample concentrations detected are at or below background concentrations.
Essential Nutrient² - Analyte is an essential human nutrient (magnesium, calcium, potassium, sodium) and is not evaluated quantitatively because toxicity values are not available.
Blank⁴ - Compound was detected in field and/or laboratory blanks.

TABLE 1-6
QUANTITATIVE RISK SUMMARY
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

	Total Cancer Risk	MEAN EPC Total Hazard Index	Total Cancer Risk	MAXIMUM EPC Total Hazard Index
CURRENT AND FUTURE USE				
SUBSURFACE SOIL (1 - 15 feet bgs) AT SOURCE AREA				
Incidental Ingestion of Subsurface Soil: Utility/Maintenance Worker	3E-07	0.01	5E-07	0.02
Inhalation of Volatiles from Soil and Groundwater: Utility/Maintenance Worker	8E-07	0.01	8E-07	0.01
TOTAL: UTILITY/MAINTENANCE WORKER	1E-06	0.02	1E-06	0.03
Incidental Ingestion of Subsurface Soil: Construction Worker	6E-07	0.4	8E-07	0.6
Inhalation of Volatiles from Groundwater and Particulates and Volatiles from Soil: Construction Worker	1E-06	0.4	1E-06	0.4
TOTAL: CONSTRUCTION WORKER	2E-06	0.8	2E-06	1
SUBSURFACE SOIL (1 - 15 feet bgs) AT PERIMETER AREA				
Incidental Ingestion of Subsurface Soil: Utility/Maintenance Worker	4E-07	0.02	7E-07	0.04
Inhalation of Volatiles from Soil and Downgradient Groundwater: Utility/Maintenance Worker	2E-08	0.00005	2E-08	0.00005
TOTAL: UTILITY/MAINTENANCE WORKER	4E-07	0.02	7E-07	0.04
Incidental Ingestion of Subsurface Soil: Construction Worker	7E-07	0.8	1E-06	1
Inhalation of Volatiles from Downgradient Groundwater and Particulates and Volatiles from Soil: Construction Worker	3E-08	0.003	3E-08	0.005
TOTAL: CONSTRUCTION WORKER	7E-07	0.8	1E-06	1
FUTURE USE				
SOURCE AREA GROUNDWATER - UNFILTERED				
Ingestion of Groundwater: Commercial/Industrial Worker	3E-04	25	6E-04	53
TOTAL: COMMERCIAL/INDUSTRIAL WORKER	3E-04	25	6E-04	53
SOURCE AREA GROUNDWATER - FILTERED				
Ingestion of Groundwater: Commercial/Industrial Worker	2E-04	24	5E-04	52
TOTAL: COMMERCIAL/INDUSTRIAL WORKER	2E-04	24	5E-04	52
DOWNGRAIDENT GROUNDWATER - UNFILTERED				
Ingestion of Groundwater: Commercial/Industrial Worker	3E-05	2	7E-05	7
TOTAL: COMMERCIAL/INDUSTRIAL WORKER	3E-05	2	7E-05	7
DOWNGRAIDENT GROUNDWATER - FILTERED				
Ingestion of Groundwater: Commercial/Industrial Worker	6E-07	2	4E-06	6
TOTAL: COMMERCIAL/INDUSTRIAL WORKER	6E-07	2	4E-06	6

NOTES:
EPC = Exposure Point Concentration

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Remedial action objectives and general response actions form the basis for identifying remedial technologies and developing remedial alternatives. This section identifies remedial response and action objectives and the general response actions to meet those objectives. Remedial technologies considered implementable, and which also address the remedial action objectives and general response actions, are identified. Candidate remedial technologies are then screened based on their applicability to site and waste characteristics. The purpose of the screening is to produce an inventory of suitable technologies that can be assembled into remedial alternatives capable of mitigating actual or potential risks at AOC 43J.

2.1 IDENTIFICATION OF REMEDIAL RESPONSE OBJECTIVES

Remedial response objectives are site-specific qualitative cleanup objectives established on the basis of the nature and distribution of contamination, the resources currently or potentially threatened, and the potential for human and environmental exposure. For AOC 43J, remedial response objectives were formulated based on environmental concerns defined in the environmental contamination assessment, risk assessment, and ARARs analysis. Response objectives are used for defining remedial action objectives and for developing appropriate remedial alternatives.

Based on the environmental contamination assessment in the RI Report, the following remedial response objectives were identified for AOC 43J:

- Protect potential commercial/industrial receptors located on Army Reserve Enclave property from exposure to groundwater having chemicals in excess of ARARs.
- Protect potential commercial/industrial receptors located off Army Reserve Enclave property from exposure to groundwater having chemicals in excess of ARARs.
- Minimize the possibility of soils contributing to groundwater

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contamination in excess of ARARs.

2.2 PRELIMINARY REMEDIATION GOALS

Preliminary Remediation Goals (PRGs) are numerical goals for site cleanup that are intended to be protective and to comply with ARARs. PRGs are based both on risk assessment and on ARARs. PRGs for AOC 43J were developed following the USEPA guidance document entitled *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk Based Preliminary Remediation Goals)*, Interim, December 1991 (RAGS Part E) (USEPA, 1991c) and OSWER Directive 9355.0-30, *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (USEPA, 1991b).

The first step in developing human health PRGs is to identify those environmental media that, in the baseline human health risk assessment, present either a cumulative current or future cancer risk greater than 1×10^{-4} or a cumulative noncarcinogenic HI greater than 1, based on reasonable maximum exposure (RME) assumptions. The RME is defined as the maximum exposure that is reasonably expected to occur at a site. It is derived for a given exposure pathway by combining the maximum exposure point concentration (EPC) of each chemical with reasonable maximum values describing the extent, frequency, and duration of exposure. The specific assumptions used in deriving the RME for each exposure scenario are discussed in detail in the Final RI Report (ABB-ES, 1996). The next step is to identify CPCs within the media that present cancer risks greater than 1×10^{-6} or an hazard quotient (HQ) greater than 1. Following identification of media of concern and CPCs, PRGs are developed and refined by considering ARARs, exposures, uncertainties and other technical factors.

Under assumptions of current land use, the baseline human health risk assessment did not identify media of concern or CPCs presenting cancer risks or HIs greater than USEPA criteria. Under assumptions of future land use, commercial/ industrial use of groundwater at AOC 43J does present potential health risks above the criteria for both source area groundwater and downgradient groundwater (Table 1-6).

2.2.1 Groundwater

Risk Evaluation: The consumption of unfiltered and filtered groundwater with maximum and mean EPCs from evaluated source areas presents cancer risks above 1×10^{-4} . Following USEPA guidance, for those media with cancer risks above 1×10^{-4} the next step is to identify those CPCs within the media that present cancer risks above 1×10^{-6} . Arsenic, benzene, and carbon tetrachloride are three CPCs that meet this criterion for the source area and downgradient groundwater.

Similarly, for noncancer risks under future use assumptions, commercial/industrial groundwater use exceeds the criterion. As seen in Table 1-6, the HIs for both the unfiltered and filtered groundwater exceed 1 for source area and downgradient groundwater. As with carcinogens, USEPA guidance states that within those media with noncancer risks above 1, the next step is to identify those CPCs within the medium whose HQ exceeds 1. Benzene, manganese, iron, carbon tetrachloride and arsenic are the only CPCs meeting this criterion from exposure to maximum concentrations detected at AOC 43J at the source area. Only manganese meets this criterion in downgradient groundwater.

Comparison with ARARs: The baseline human health risk assessment also identified source area and downgradient groundwater analytes that exceeded federal or Massachusetts drinking water standards. These analytes are benzene, carbon tetrachloride, ethylbenzene, toluene, aluminum, arsenic, cadmium, iron, lead, and manganese in source area groundwater. Aluminum, iron, and manganese only have secondary maximum contaminant level (SMCL) drinking water standards which are not ARARs. Therefore only benzene, carbon tetrachloride, ethylbenzene, toluene, arsenic, cadmium, and lead exceed ARARs in source or downgradient groundwater.

Tables 2-1 and 2-2 (for source area groundwater and downgradient groundwater, respectively) list CPCs from the baseline human health risk assessment that either exceed ARARs or present cancer risks above 10^{-6} or HQs greater than 1. The tables provide the average and maximum EPCs for these analytes and compare these values with:

- ARARs (federal and Massachusetts drinking water standard concentrations) identified in Section 4.0 of the Final RI Report (ABB-ES, 1996).

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- The Fort Devens background concentrations of inorganics in unfiltered groundwater samples as discussed in Section 4.0 and Appendix L of the Final RI Report (ABB-ES, 1996).
- The average and maximum analyte concentrations detected in groundwater upgradient of the source area as detailed in Section 7.0 of the Final RI Report (ABB-ES, 1996).

Tables 2-1 and 2-2 also include all CPCs identified in the baseline human health risk assessment that present cancer risks above 1×10^{-6} or an HQ greater than 1.0. PRGs are based on the maximum concentration levels (MCLs) when available and default to risk-based values only if an MCL is not available. MCL-based PRGs are proposed in Tables 2-1 and 2-2 as either the lowest drinking water standard or as the Fort Devens inorganic background concentration, whichever is highest. As seen in Table 2-1 for source area groundwater, ARARs-based PRGs are proposed for benzene, carbon tetrachloride, ethylbenzene, toluene, and arsenic. PRGs equal to Fort Devens inorganic background concentrations are proposed for iron and manganese because background concentrations exceed the risk-based concentration derived from the available reference dose values. These reference dose values are 3.0×10^{-1} and 5.0×10^{-3} for iron and manganese, respectively.

Similarly, PRGs are determined in Table 2-2 for those analytes that exceed ARARs (benzene) or for those analytes that present an HQ greater than 1.0 (manganese) in downgradient area groundwater. Risk-based PRGs were not developed for AOC 43J. Figures 2-1 and 2-2 show the estimated MCL concentration contours for benzene, toluene, ethylbenzene, and carbon tetrachloride for Rounds Five and Six, respectively. Carbon tetrachloride was detected only in Round Six. The high detection limits from sample dilution (standard procedure) may have masked the presence of carbon tetrachloride in Round Five. See additional details in Subsection 1.3.4 Off-Site Groundwater Laboratory Analytical Sample Results.

The lead concentration above the Fort Devens background concentration in source area groundwater is directly attributable to the high concentration of suspended solids in the sample (Table 2-1). Lead concentration exceeded the MCL in only one groundwater sample collected within the source area ($26.7 \mu\text{g/L}$ in 2446-02 during Round Six) from the two rounds evaluated in the risk

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assessment. The TSS concentration for that sample was 3,130,000 $\mu\text{g/L}$, which is more than four times the average TSS concentration of the other 11 samples. Lead concentrations in filtered source area groundwater samples from Rounds Five and Six were all below federal and Commonwealth standards.

Cadmium was detected in only one of the 12 unfiltered groundwater samples evaluated in the risk assessment at AOC 43J (5.79 $\mu\text{g/L}$ in the unfiltered Round Five sample from XJM-93-03X). There was no detection of cadmium in filtered samples. Cadmium was not determined to be a CPC in site soils based on RI results. Based on these data, the detection of cadmium is not believed to be associated with activities that have occurred at AOC 43J.

Inorganic Solubility: Tables 2-1 and 2-2 also show that although EPCs for arsenic, manganese, and iron in the source area exceed the MCL (arsenic) or Fort Devens background (arsenic, manganese and iron), the concentrations of these analytes in the upgradient monitoring well (XJM-93-01X) also exceed the MCL or Fort Devens background concentrations. This implies that these inorganics are not specific to AOC 43J activities. However, PRGs for these inorganics have been established. It appears that AOC 43J activities may be effecting the solubility of these analytes. Because ARAR or risk exceedances are largely due to the increase in solubility, measurements for compliance with the inorganic PRGs will be performed by filtered sampling. Otherwise, as presented by upgradient well results, PRGs based upon unfiltered samples would never be achievable because of the presence of elevated unfiltered inorganic concentrations upgradient of the source area.

It is noted that filtered source area samples contain higher concentrations of arsenic, iron, and manganese than respective upgradient samples. The higher dissolved concentrations of these inorganics are likely because of ongoing biological degradation of the site-related organic contaminants. Studies show that hydrocarbon biodegradation is essentially an oxidation-reduction reaction where the hydrocarbon is oxidized (donates electrons) and an electron acceptor, such as oxygen, is reduced (accepts electrons) (Borden, 1995; McAllister, 1994).

Under aerobic conditions the electron acceptor is oxygen. When oxygen is depleted, and nitrate (and other oxidized forms of nitrogen) are present, anaerobic microorganisms will use nitrate instead of oxygen as a terminal electron acceptor. At this time in the orderly succession of oxidation-reduction reactions,

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manganese oxides (Mn[IV]) are also reduced to Mn(II), increasing manganese concentration in solution. Once oxygen, nitrate and manganese acceptors are depleted, subsurface microorganisms use oxidized ferric iron (Fe[III]) as an electron acceptor. The reduction of Fe(III) results in elevated concentrations of the more soluble ferrous (Fe[II]) ion in solution.

Sulfate-reducing and methanogenic (methane-generating) degradation generally follow ferric iron reduction in the sequence of microbial induced oxidation-reduction processes. The farther the progression in this oxidation-reduction sequence, the lower the oxidation-reduction potential (ORP). Arsenic is not directly identified as an electron acceptor in microbial induced processes. However, its increased solubility is likely because of the changed chemical environment. For instance, arsenic is more soluble at low ORP (As[III] is more soluble than As[V]).

Table 2-3 presents the average measurements of nitrite/nitrate, sulfate, ORP from groundwater monitoring wells upgradient of the source, at the source area, at the perimeter, and downgradient (where benzene concentrations were less than 5 $\mu\text{g/L}$). Reduced average nitrate/nitrite, phosphate, sulfate, and ORP measurements in the source area are indicative that these microbial-induced oxidation-reduction processes are occurring at AOC 43J and causing some inorganics to become more soluble.

Downgradient wells reveal lower nitrate, sulfate and phosphate concentrations than nearer the source area which might be considered contrary to expected trends. However, these exceptions may be due to the "source area" wells being slightly upgradient of the true center of the plume (as noted by the soil concentration contours in Figures 2-3 through 2-8). Nitrate, sulfate and phosphate concentrations may decrease farther downgradient within the plume as appears to be observed in downgradient wells. Lovely, Chapelle, and Woodward (Lovely, 1994) note that when shallow aquifers are heavily contaminated with organic compounds, it is generally difficult to delineate the distribution of the anoxic redox processes. They further state that reduced products that are actively produced near the source of organic contamination may persist in the groundwater as it moves downgradient into areas where there is little or no ongoing production of these compounds. Therefore observation of reduced nitrate, phosphate and sulfate in downgradient wells are not necessarily inconsistent with expected trends.

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2.2.2 Subsurface Soil

Under assumptions of current and future land use, the baseline human health risk assessment did not identify CPCs within subsurface soil that present cancer risks or HIs greater than USEPA criteria (Table 1-6). Additionally, there are currently no chemical-specific ARARs which govern the extent of site remediation for subsurface soil at AOC 43J. Furthermore, there are no exceedances of the USEPA Region III Commercial/Industrial Risk-Based Soil Ingestion Concentration Tables referenced as To Be Considered guidance in the RI Report. However, because groundwater at AOC 43J does present potential health risks above the target risk range, remedial response actions will be established to minimize the possibility of soils contributing to groundwater contamination in excess of PRGs. Soil areas were evaluated qualitatively to identify areas that could be influencing groundwater and where soil remedial action would be appropriate. However, success of the remedial action of the operable unit at AOC 43J will be based on meeting ARAR-driven groundwater PRGs.

Field analytical and off-site analytical laboratory data from field investigations show that the former gasoline and waste oil USTs were the sources for the existing subsurface soil contamination at AOC 43J. The highest concentrations of three of the four groundwater CPCs (benzene, ethylbenzene and toluene) were detected in soil at, or just below, the water table, at depths ranging from 7 to 9 feet bgs. Carbon tetrachloride, the fourth groundwater CPC was not detected in any off-site laboratory soil samples (not analyzed in field screening samples). Figures 2-3 through 2-8 show concentration contours depicting the areas of highest soil contamination for benzene, ethylbenzene and toluene. These areas collocated closely with the highest contaminant concentrations within groundwater (Figures 2-1 and 2-2).

It is believed that no actual soil source (free product or smear zone) remains at the site, but that the soil concentrations are in general equilibrium with groundwater concentrations. This is demonstrated in Table A-1 in Appendix A. BTEX groundwater concentrations were closely predicted based on a soil/water partitioning equation and average soil concentrations. Computed water concentrations were 7, 11, 1.1, and 19 mg/L for ethylbenzene, toluene, benzene, and xylene. Actual detected maximum groundwater concentrations were 4, 8, 0.3, and 9 mg/L, respectively. Furthermore, if a free product smear zone was present, soil concentrations would be expected to be higher than observed concentrations.

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Contaminant concentrations also appear to diminish near the former sources. This indicates that the soil concentrations are more reflective of the groundwater plume than a smear zone which would be expected to extend back to the former sources. It is also indicative that the Army has removed successfully any gross contamination from the former UST areas which would continue to contaminate the groundwater. Details of the source removals are discussed in Subsection 1.2.1 of this report. The implications are that additional soil removal would provide little benefit in remediating groundwater. Clean backfill would become similarly contaminated once in contact with the groundwater plume. Therefore soil remedial action, if implemented, would be best applied within the areas shown in Figures 2-3 through 2-8 but only in conjunction with a groundwater treatment general response action.

2.3 REMEDIAL ACTION OBJECTIVES

Remedial action objectives are medium- or operable unit-specific, quantitative goals defining the extent of cleanup required to achieve response objectives. They specify CPCs, exposure routes and receptors, and PRGs. Remedial action objectives are used as the framework for developing remedial alternatives. The remedial action objectives are formulated to achieve the overall goal of USEPA of protecting human health and the environment. Table 2-4 lists remedial action objectives for AOC 43J.

2.4 GENERAL RESPONSE ACTIONS

General response actions describe categories of remedial actions that may be employed to satisfy remedial action objectives. General response actions provide the basis for identifying specific remedial technologies.

Applicable general response actions to meet groundwater remedial action objectives are listed in Table 2-5 in conjunction with potential remedial technologies. The general response actions for groundwater focus on preventing possible future commercial/industrial use of groundwater near the source of contamination on Army Reserve Enclave property; and on preventing possible future commercial/industrial use of groundwater downgradient off Army Reserve

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Enclave property.

The baseline human health risk assessment did not identify potential risks greater than USEPA threshold criteria for soils. The general response actions for soil focus on minimizing the possibility of soils contributing to groundwater contamination in excess of groundwater PRGs. However, sampling results indicate that site soils may not be acting as a significant source of groundwater contamination. Contaminant concentrations within the soil are in close equilibrium with groundwater contaminant concentrations. Table 2-6 presents applicable response actions and remedial technologies to meet the remedial action objective associated with the potential source area soils. These general response actions are in accordance with recommendations made in USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988). General response actions describe categories of remedial actions that may be employed to satisfy remedial action objectives. General response actions provide the basis for identifying specific remedial technologies.

2.5 TECHNOLOGY IDENTIFICATION

Categories of remedial technologies and specific process options were identified based on a review of literature, vendor information, performance data, and experience in developing other FSs under CERCLA. Of these process options, 15 were selected as being potentially applicable to petroleum-contaminated media and attaining the preliminary remedial response objectives. Selected groundwater technologies focus on organic contamination. This is based on the premise that the naturally occurring inorganic chemicals within the groundwater have become more soluble as a result of microbial induced oxidation-reduction processes (Subsection 2.2.1). Removal of the organics will return the groundwater quality (oxygen content, ORP, pH) to upgradient conditions resulting in a return of the more insoluble inorganic fractions. For ex-situ groundwater treatment process options, inorganic pretreatment that is required for effective treatment of organics and to meet discharge requirements, is included as part of the organic treatment process option.

Technologies selected for soils at AOC 43J are the USEPA presumptive remedies for CERCLA sites with VOCs in soil (USEPA, 1993) with inclusion of the asphalt

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batching technology, also for treatment of petroleum contaminated soils. Disposal response actions are also included for instances where soil volumes are minimal and are typical of UST removal sites such as around the former waste oil UST and historic gas station UST. Tables 2-7 and 2-8 provide descriptions for groundwater and source area soils process options.

2.6 TECHNOLOGY SCREENING

The technology screening process reduces the number of potentially applicable technologies and process options by evaluating factors that may influence process option effectiveness and implementability. This overall screening is consistent with the guidance for conducting FSs under CERCLA (USEPA, 1988).

The screening process assesses each technology or process option for its probable effectiveness and implementability with regard to site-specific conditions, known and suspected contaminants, and affected environmental media. The effectiveness evaluation focuses on: (1) whether the technology is capable of handling the estimated areas or volumes of media and meeting the contaminant reduction goals identified in the remedial action objectives; (2) the effectiveness of the technology in protecting human health during the construction and implementation phase; and (3) how proven and reliable the technology is with respect to the contaminants and conditions at the site. Implementability encompasses both the technical and institutional feasibility of implementing a technology. Effectiveness and implementability are incorporated into two screening criteria: waste- and site-limiting characteristics.

Waste-limiting characteristics largely establish the effectiveness and performance of a technology; site-limiting characteristics affect implementability of a technology. Waste-limiting characteristics consider the suitability of a technology based on contaminant types, individual compound properties (e.g., volatility, solubility, specific gravity, adsorption potential, and biodegradability), and interactions that may occur between mixtures of compounds (e.g., reactions and increased solubility). Site-limiting characteristics consider the effect of site-specific physical features, including topography, buildings, underground utilities, available space, and proximity to sensitive operations on the implementability of a technology. Technology screening based on waste- and site-limiting characteristics serves a two-fold purpose of screening out technologies

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whose applicability is limited by site-specific waste or site considerations, while retaining as many potentially applicable technologies as possible.

Tables 2-9 and 2-10 summarize the groundwater and soil technology screening phase for AOC 43J. Technologies and process options judged ineffective or not implementable were eliminated from further consideration.

Table 2-11 summarizes the groundwater and source area soil technologies retained for further consideration. The technologies retained following screening represent an inventory of technologies considered most suitable for AOC 43J. Technologies retained in this section may be used to develop remedial alternatives. Treatability/pilot studies may be required prior to final selection to confirm the effectiveness of a given technology or process option.

2.7 PROCESS OPTION EVALUATION (CARBON ADSORPTION AND UV OXIDATION)

For some general response actions more than one process option is retained. For groundwater, limited action, zoning restrictions, deed restrictions, and groundwater monitoring were all retained. Each will be carried forward for incorporation into alternatives. For collection, interceptor trenches and extraction wells were both retained and will be evaluated in the alternative screening based on groundwater modeling and/or geologic constraints. In these instances, more than one process option was retained because the processes were sufficiently different in their performance that one would not adequately represent the other. Similarly, all retained soil process options will be incorporated into alternatives. However, for groundwater treatment there were two ex-situ groundwater process options retained, ultraviolet (UV) oxidation and granular activated carbon (GAC) adsorption. These process options are evaluated in more detail within this section and a single process option is retained.

CERCLA guidance recommends that these process options be evaluated based on their effectiveness, implementability and relative cost. These criteria are described in detail in Section 3. The process option retained from this evaluation will be used to develop remedial alternatives for the groundwater at AOC 43J. This intermediate evaluation step is performed to select a representative process option for the remedial technologies and streamline the FS process by reducing the number of alternatives developed and evaluated (USEPA, 1988).

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The process options of GAC adsorption and UV oxidation would be used as an ex-situ treatment technology for all alternatives that entail extraction (collection) of groundwater. GAC adsorption is a physical separation process in which contaminated groundwater is passed through a bed (drum) of GAC which selectively adsorbs the organic contaminants (adsorbate) onto the carbon (adsorbent). When the GAC has been utilized to its maximum adsorptive capacity ("spent"), it is then removed for disposal, destruction, or regeneration.

UV oxidation involves pumping contaminated groundwater through a stainless steel oxidation chamber containing UV lamps. The UV radiation and simultaneous application of a chemical oxidant (hydrogen peroxide) promote a rapid breakdown (destruction) of the dissolved organic contaminants. When the reaction is carried to completion, hydrocarbon contaminants are converted to carbon dioxide and water. Any halogens present in the organic molecule are converted to halides.

2.7.1 Effectiveness

Both GAC adsorption and UV oxidation would be effective at mitigating the risks associated with groundwater contamination at AOC 43J. GAC will adsorb the organic CPCs from the groundwater onto the carbon thereby reducing the toxicity and volume of contaminants through treatment. UV oxidation achieves the same results through destruction of the contaminants within the groundwater. Both processes are likely to be affected by the elevated inorganic and suspended solids concentrations at AOC 43J and pretreatment for inorganic and suspended solid removal/reduction will be required. UV oxidation is more susceptible to loss in efficiency under these conditions because the suspended solids and oxidized inorganics can impede the passage of ultraviolet radiation. Some UV units come equipped with automated lamp cleaners to minimize the need to clean the lamps manually.

The GAC adsorption process option may create a slightly greater exposure to human health and the environment during implementation because of the handling and transportation of the spent carbon to an off-site regeneration or treatment, storage and disposal (TSD) facility. The time taken to treat the groundwater would be the same for either process option because the low effective pumping rate from the aquifer is the controlling factor.

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2.7.2 Implementability

Both process options are technically feasible for mitigating the risk associated with groundwater contamination. UV oxidation is a more complex process requiring pilot testing to optimize UV light intensity, residence time, and oxidant dose rates to achieve effluent limitations. Because of the low flow conditions, the UV unit would probably come equipped with a holding tank and would be programmed to run when the water level in the tank rises above a control point. The UV system would also have greater power requirements than the GAC adsorption process option. Power needs at the site would need to be assessed. Neither process option would prevent further remedial action should it be required in the future.

2.7.3 Cost

For comparison purposes, costs were based upon treatment of groundwater at a 1 gallon per minute (gpm) flow rate over a period of 30 years at a discount rate of 10%. Operation and maintenance costs for the UV system includes a weekly site visit to record meter readings of light intensity, oxidant dose, and flow rates; periodic cleaning of UV lights; UV bulb replacement; power costs; and pretreatment expenditures.

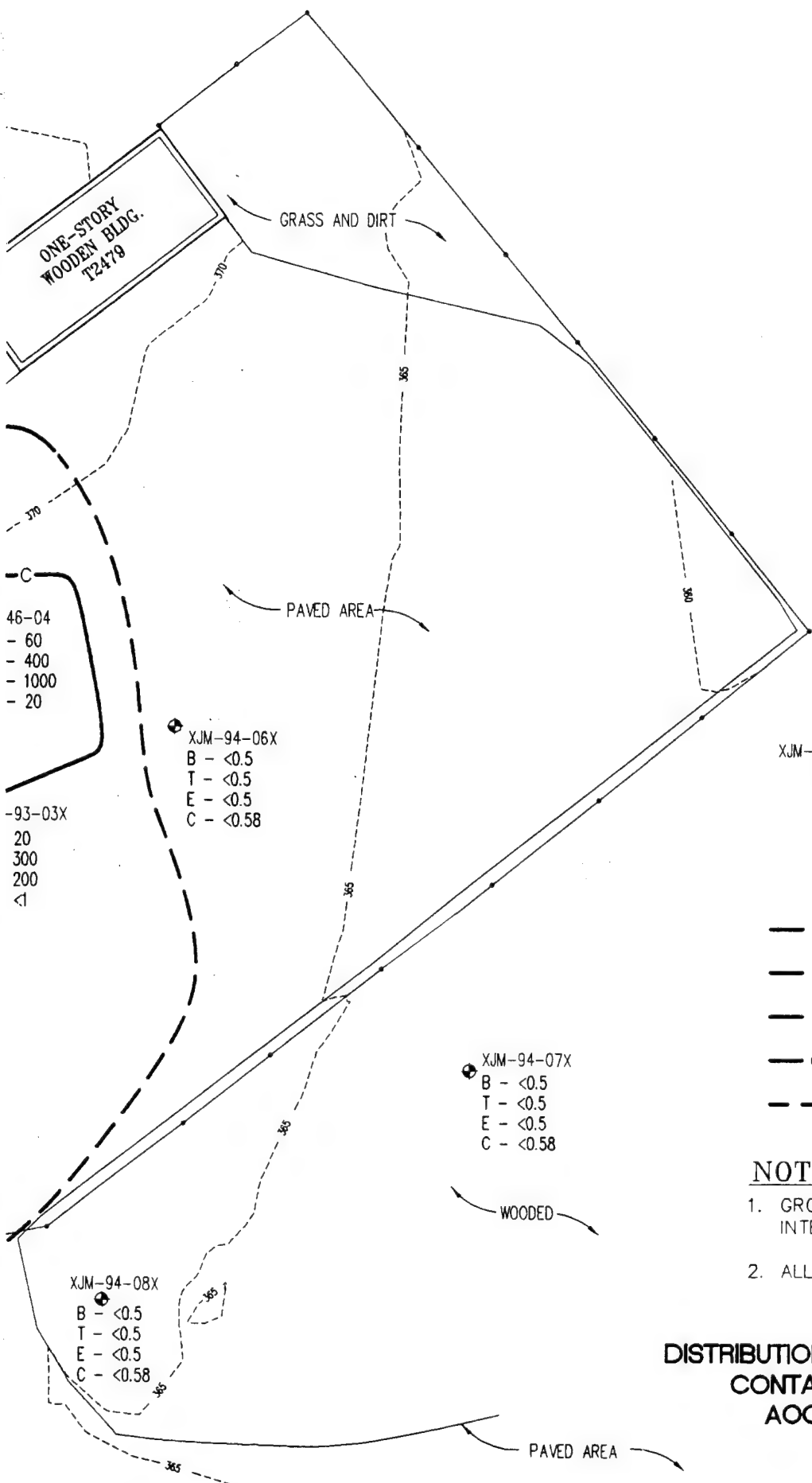
Operation and maintenance costs for the GAC system includes a weekly site visit to check flow rates and system conditions; power costs; GAC purchase and disposal costs; and pretreatment expenditures. Approximate costs for both process options are shown below:

UV Oxidation	Capital:	\$ 399,125
	O&M Present Worth:	\$ 811,395
	Total Present Worth:	\$ 1,210,520
GAC Adsorption	Capital:	\$ 188,190
	O&M Present Worth:	\$ 465,078
	Total Present Worth:	\$ 653,268

2.7.4 Process Option Selection

Because of higher costs and more stringent pretreatment requirements, UV oxidation will be eliminated from further evaluation.

ABB Environmental Services, Inc.



XJM-94-05X

MONITORING WELL

CHAIN LINK FENCE WITH BARBED WIRE TOP

ESTIMATED MCL CONTOURS

B — BENZENE — 5 ug/L

T — TOLUENE — 1000 ug/L

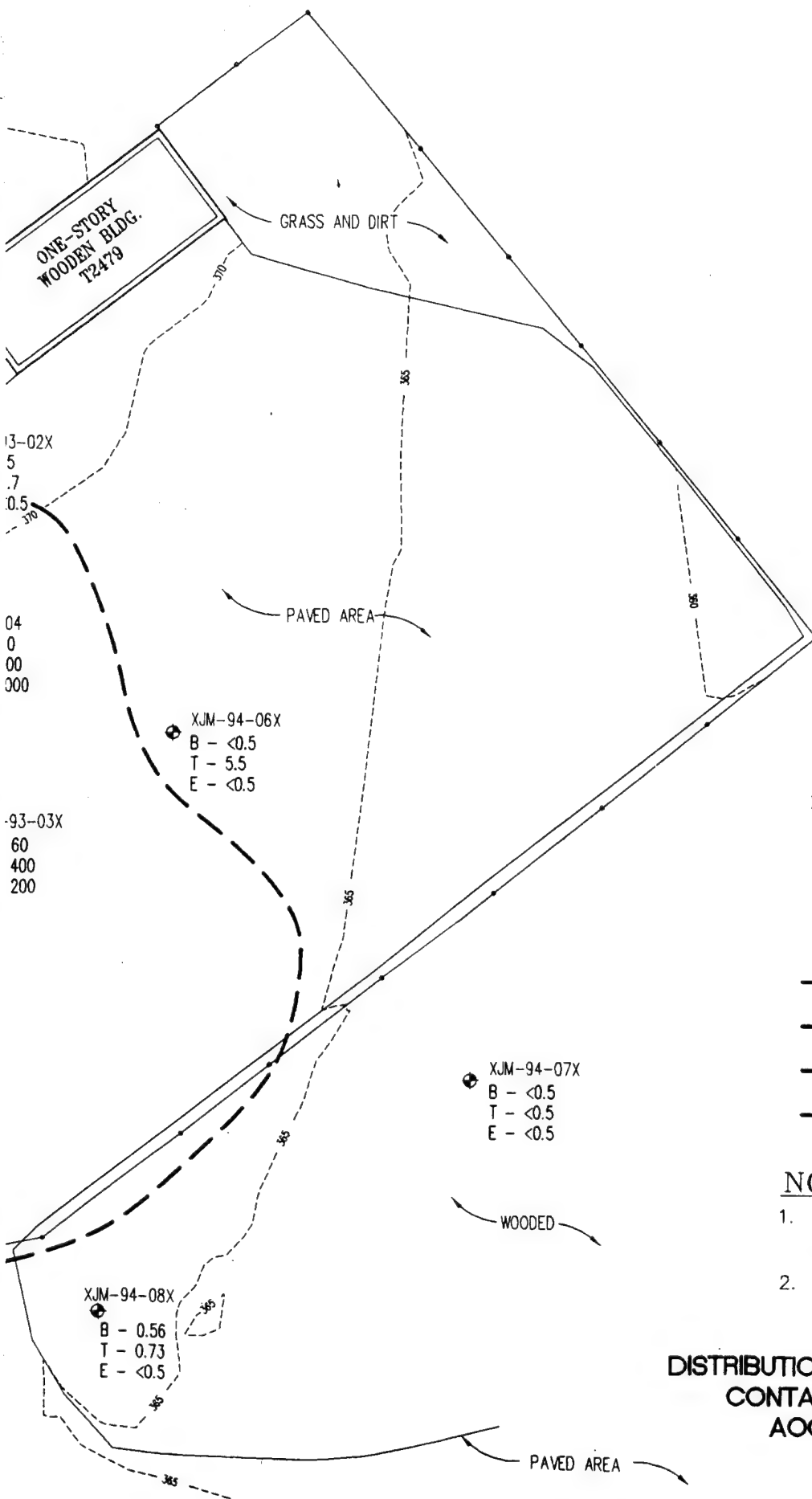
E — ETHYLBENZENE — 700 ug/L

C — CARBON TETRACHLORIDE — 5 ug/L

— — — INDICATES ASSUMPTION DUE TO LACK OF DATA POINTS

1. GROUND SURFACE ELEVATION CONTOUR INTERVAL IS 5 FEET.
2. ALL CONCENTRATIONS IN $\mu\text{g/L}$.

FIGURE 2-1
DISTRIBUTION OF ORGANIC GROUNDWATER
CONTAMINATION ABOVE MCL ON 3/95
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA



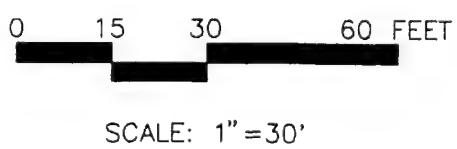
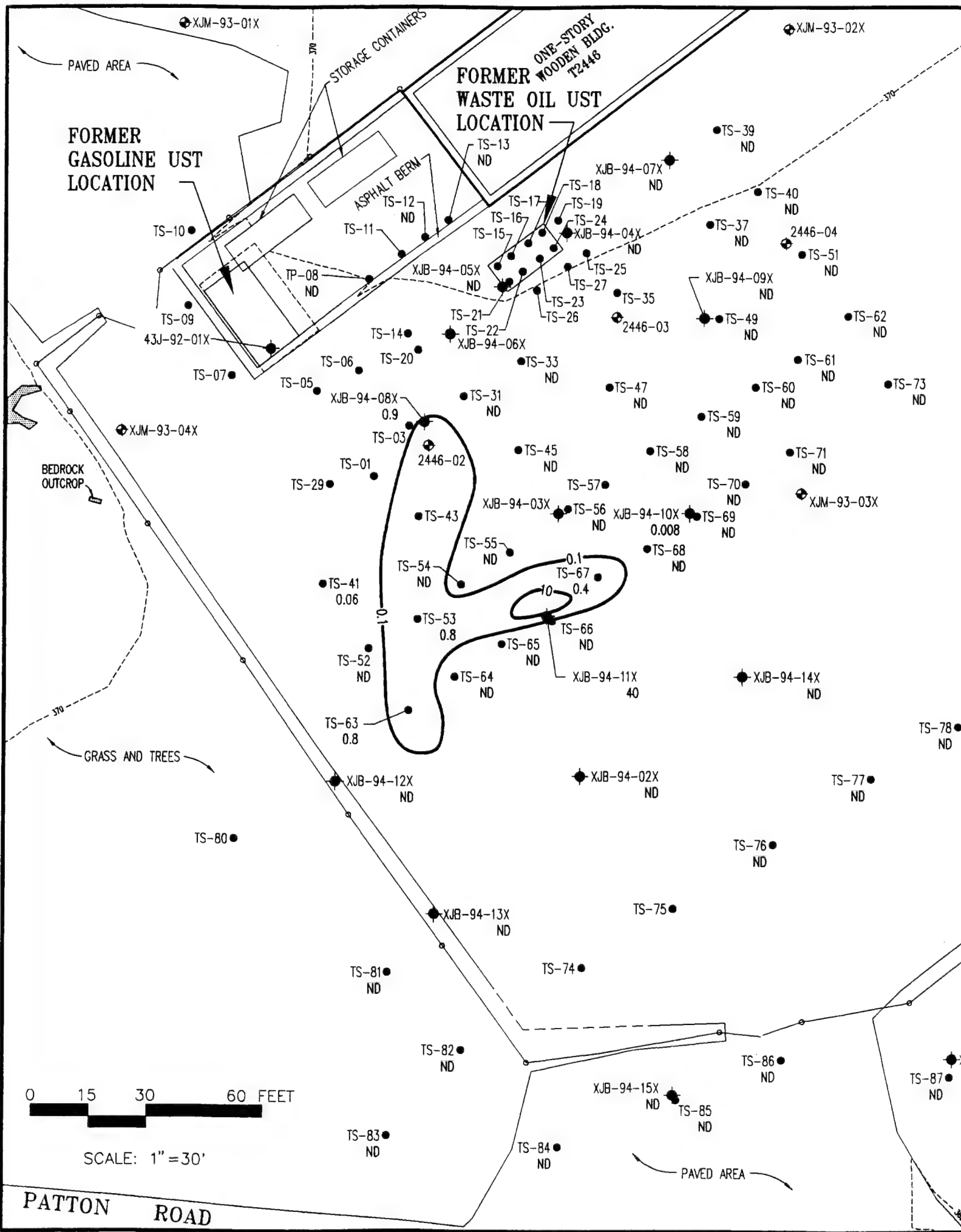
LEGEND

- XJM-94-05X MONITORING WELL
- CHAIN LINK FENCE WITH BARBED WIRE TOP
- ESTIMATED MCL CONTOURS
- B — BENZENE — 5 ug/L
 - T — TOLUENE — 1000 ug/L
 - E — ETHYLBENZENE — 700 ug/L
 - INDICATES ASSUMPTION DUE TO LACK OF DATA POINTS

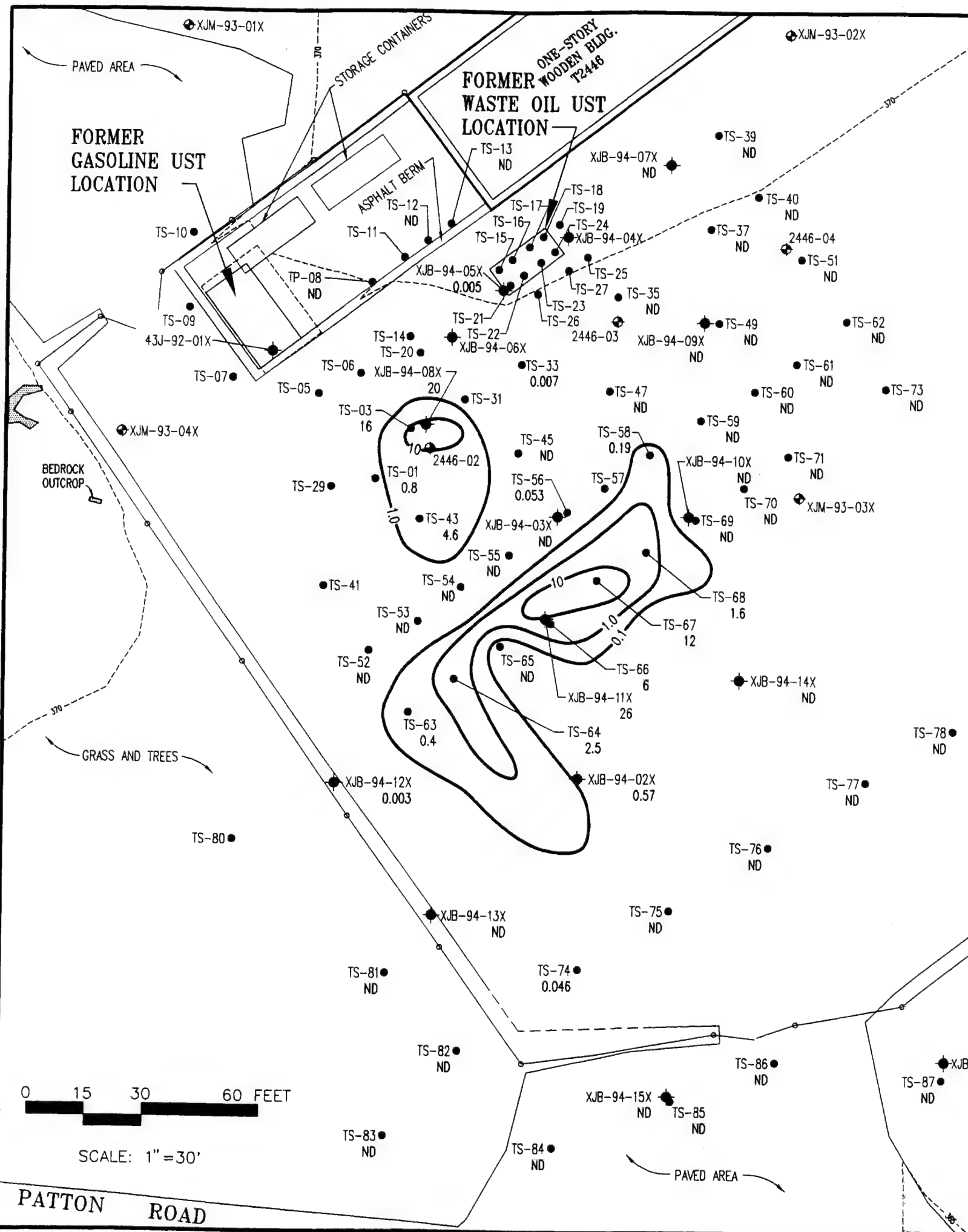
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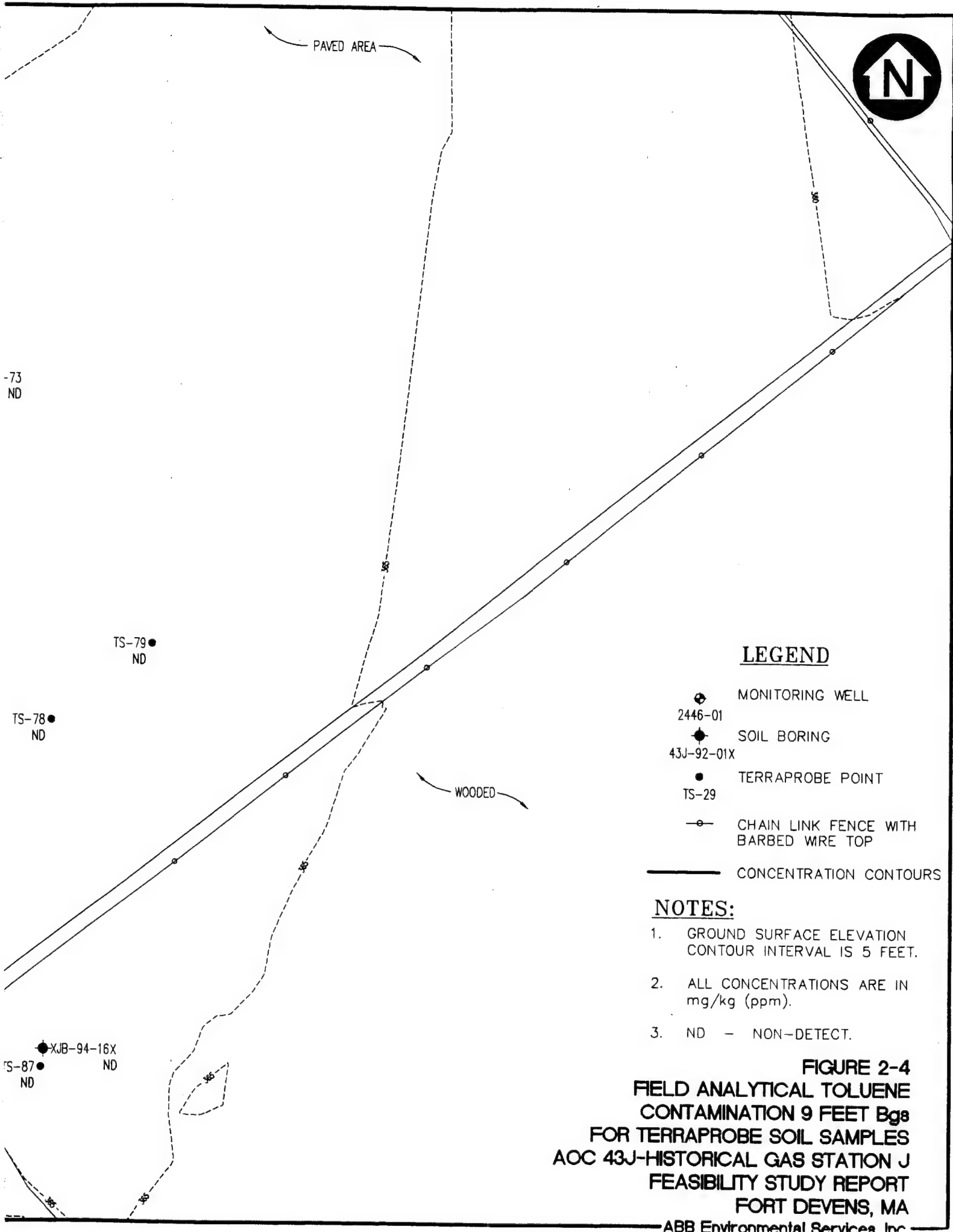
- GROUND SURFACE ELEVATION CONTOUR INTERVAL IS 5 FEET.
- ALL CONCENTRATIONS IN ug/L.

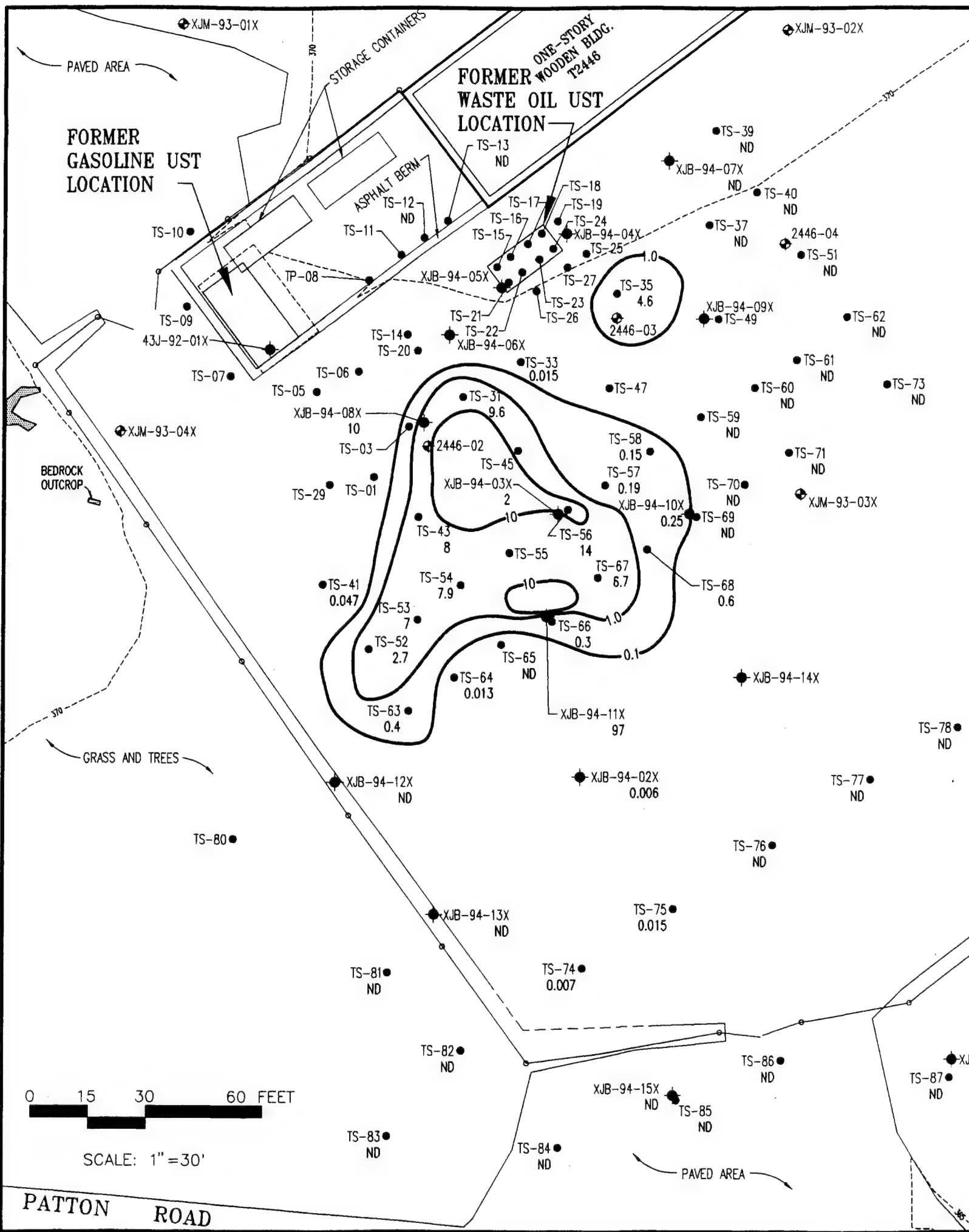
FIGURE 2-2
DISTRIBUTION OF ORGANIC GROUNDWATER
CONTAMINATION ABOVE MCL ON 12/94
AOC 43J-HISTORIC GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA

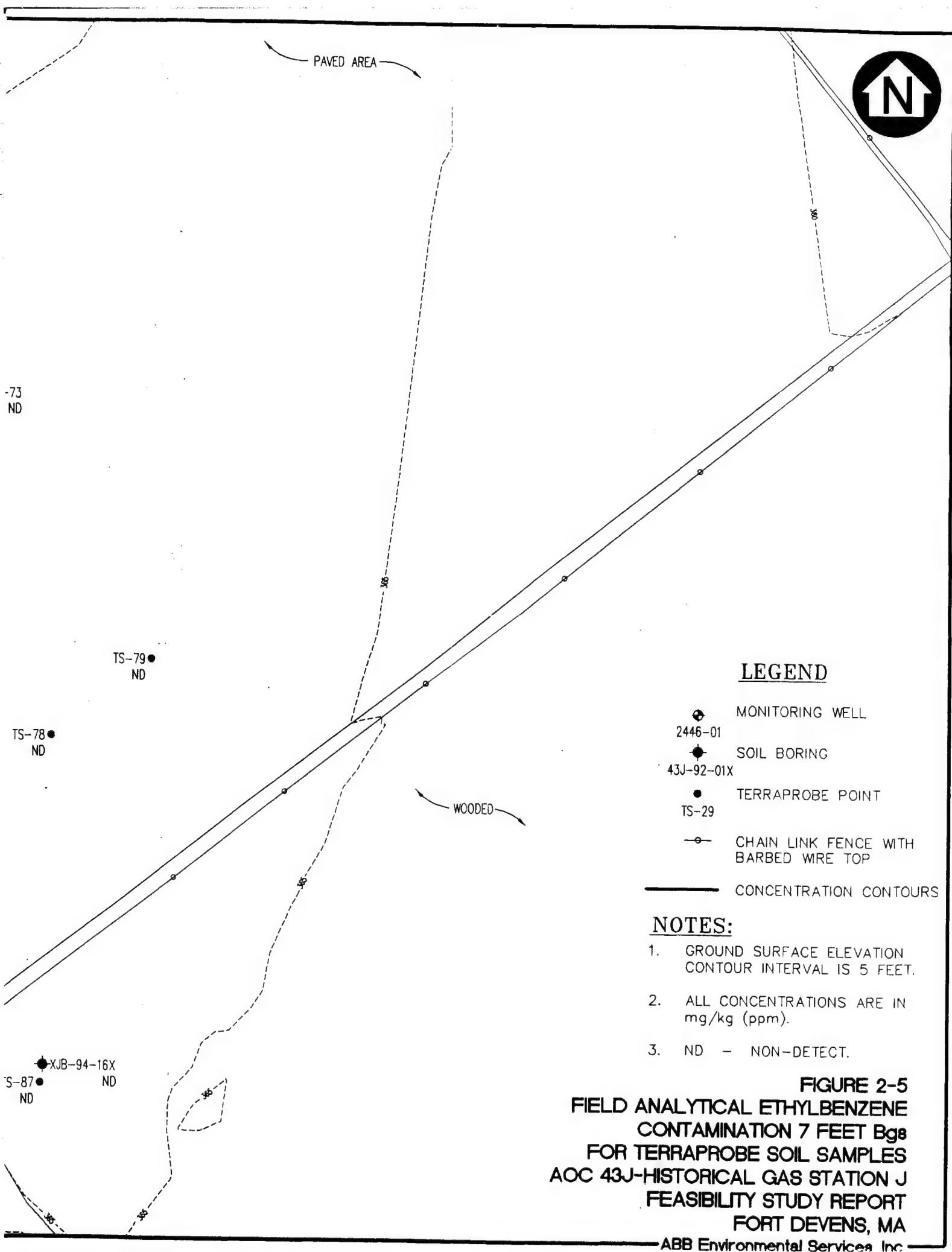


PATTON ROAD









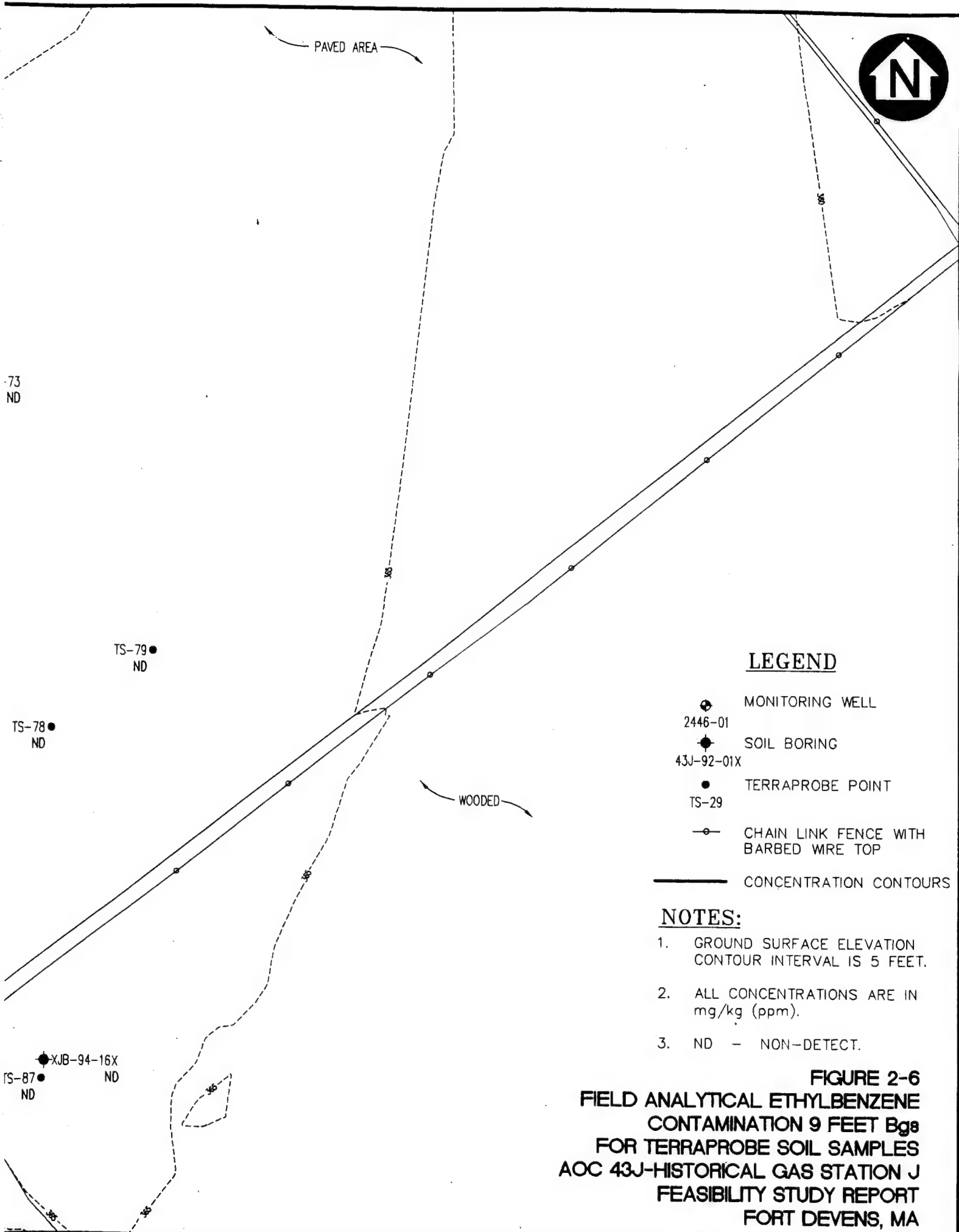
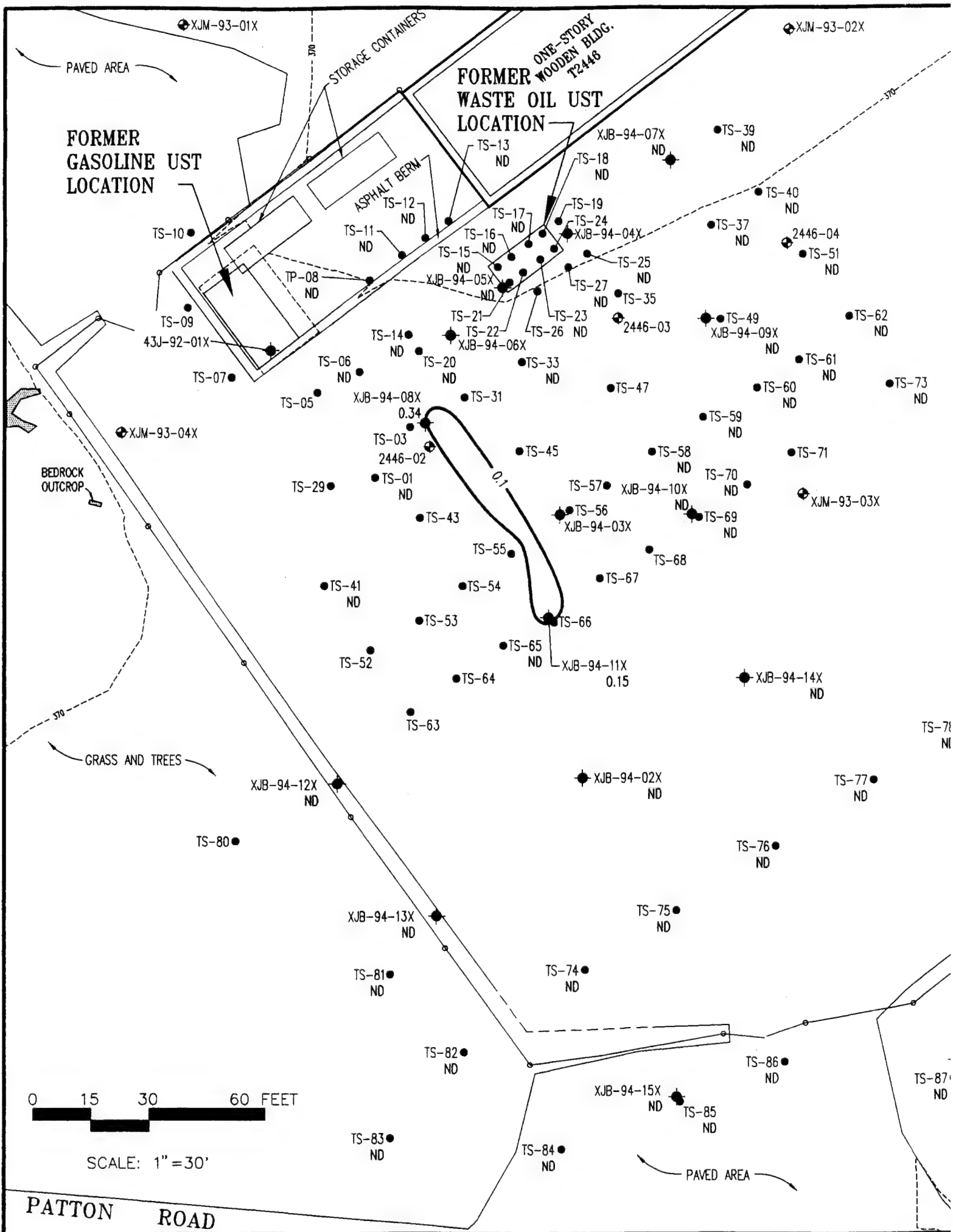
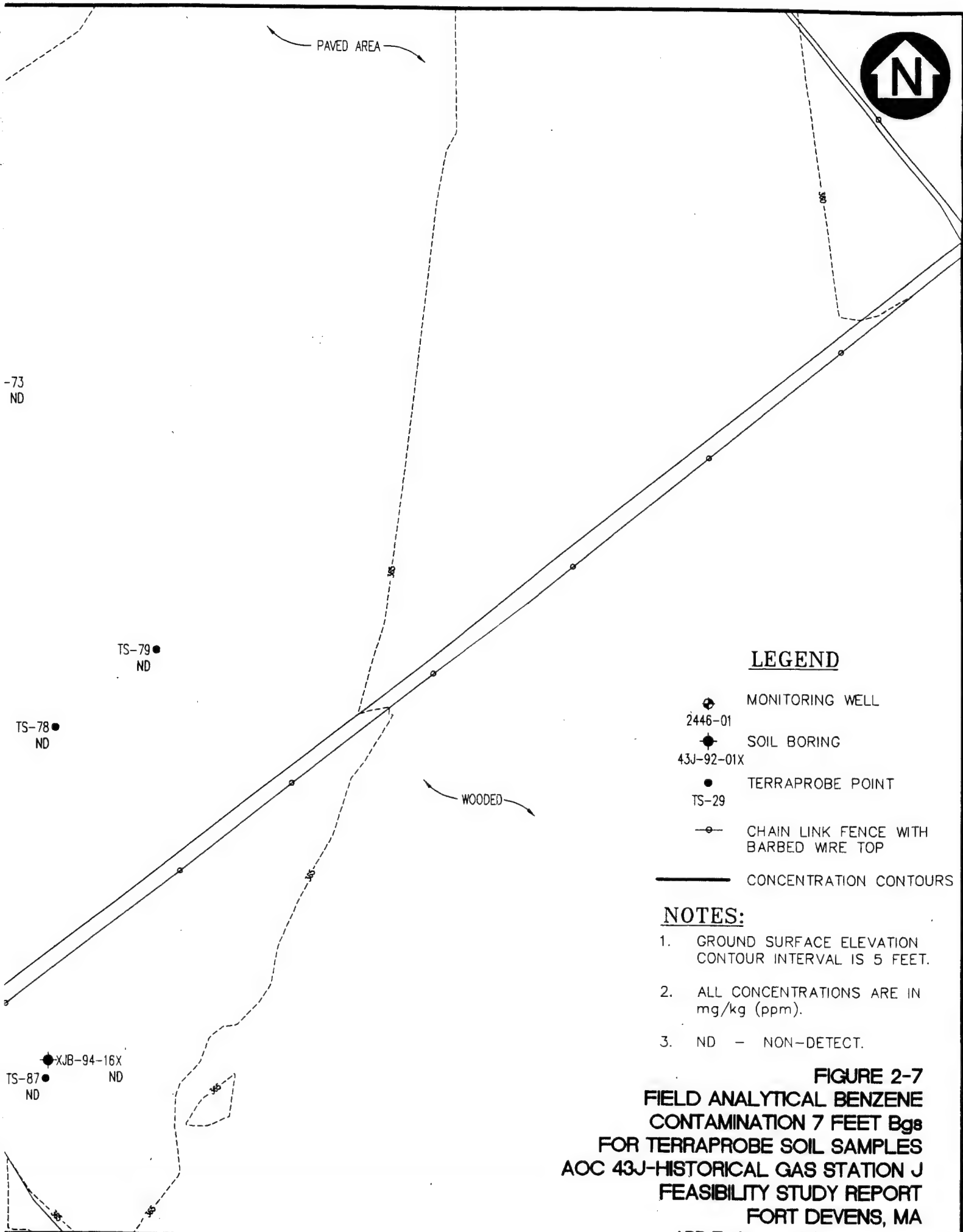
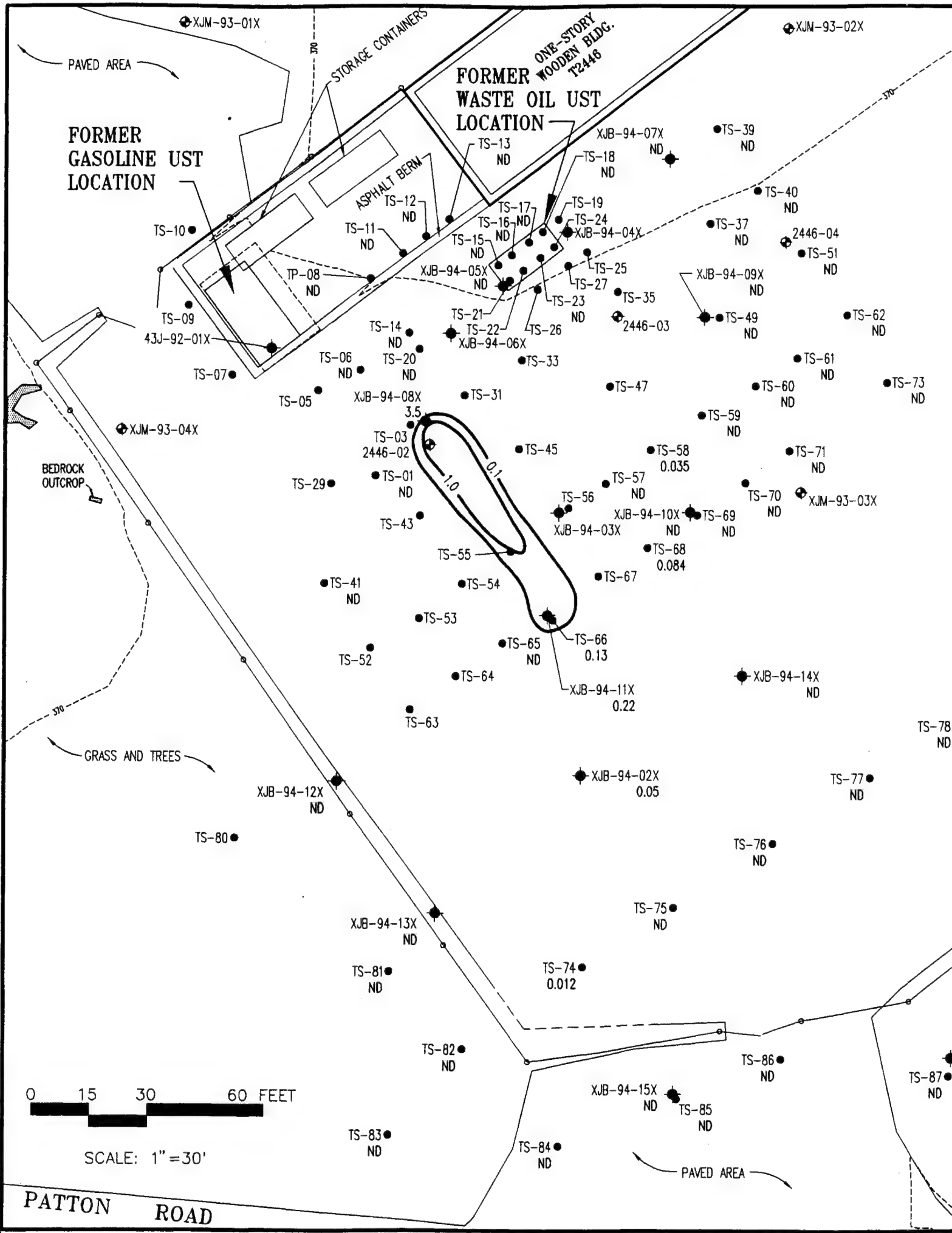


FIGURE 2-6
FIELD ANALYTICAL ETHYLBENZENE
CONTAMINATION 9 FEET Bgs
FOR TERRAPROBE SOIL SAMPLES
AOC 43J-HISTORICAL GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA







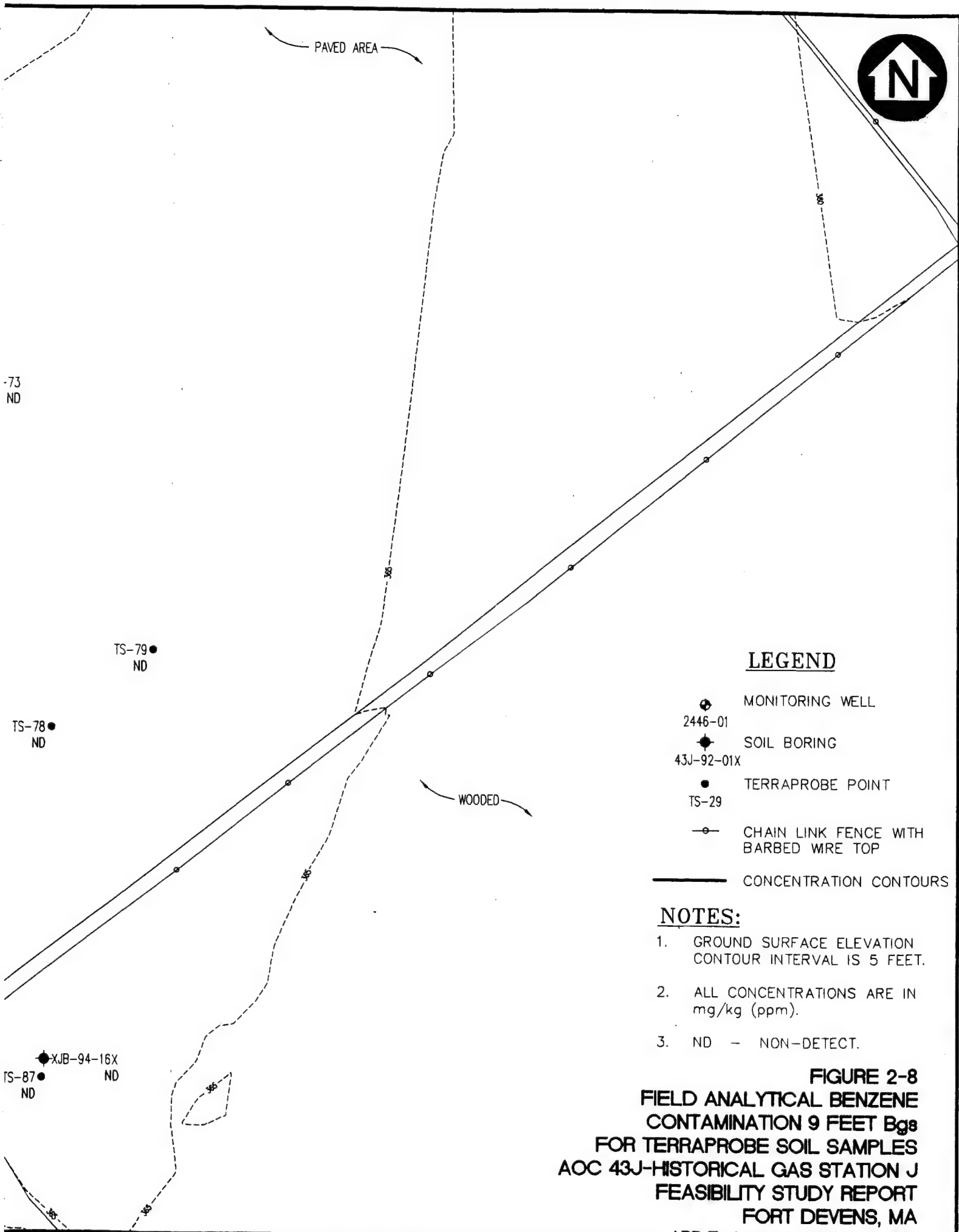


FIGURE 2-8
FIELD ANALYTICAL BENZENE
CONTAMINATION 9 FEET Bgs
FOR TERRAPROBE SOIL SAMPLES
AOC 43J-HISTORICAL GAS STATION J
FEASIBILITY STUDY REPORT
FORT DEVENS, MA
 ABB Environmental Services, Inc.

TABLE 2-1
PROPOSED PRELIMINARY REMEDIATION GOALS
FOR SOURCE AREA GROUNDWATER
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

CHEMICAL OF POTENTIAL CONCERN ⁽¹⁾	SOURCE AREA GROUNDWATER ⁽⁴⁾				UPGRADIENT GROUNDWATER ⁽⁵⁾				BKGRND ⁽⁹⁾ (µg/L)	SMCL (µg/L)	ARARs		PROPOSED PRG (µg/L)(10)
	AVERAGE EPC (µg/L)		MAXIMUM EPC (µg/L)		AVERAGE EPC (µg/L)		MAXIMUM EPC (µg/L)				MCL (µg/L)	MMCL (µg/L)	
	UNFILTERED	FILTERED	UNFILTERED	FILTERED	UNFILTERED	FILTERED	UNFILTERED	FILTERED					
INORGANICS													
Arsenic	40	30	87.8	72.6	11.29	ND	21.3	ND	10.5	-	50	50	50
Cadmium	2	ND	5.79	ND	ND	ND	ND	ND	4.01	-	5	5	-(6)
Iron	21,000	10,500	49,700	30,000	31,050	51.05	43,200	63.3	9,100	300	-	-	9,100
Lead	8	2	26.7	6.18	16.4	ND	24	ND	4.25	-	15(3)	15	-(7)
Manganese	9,600	9,600	18,200	18,400	1,066	67.4	1,670	107	291	50	-	-	291
VOCs													
Benzene	100	NA	300	NA	ND	NA	ND	NA	ND	-	5	5	5
Carbon Tetrachloride	20	NA	100	NA	ND	NA	ND	NA	ND	-	5	5	5
Ethylbenzene	1,300	NA	3,000	NA	ND	NA	ND	NA	ND	-	700	700	700
Toluene	1,500	NA	7,000	NA	ND	NA	ND	NA	ND	-	1,000	1,000	1,000

Notes:

- (1) "Drinking Water Regulations and Health Advisories", May 1995, USEPA Office of Water
 - (2) "Drinking Water Standards & Guidelines for Chemicals in Massachusetts Drinking Waters", Autumn 1994, Massachusetts Department of Environmental Protection
 - (3) Action Level.
 - (4) Based on samples XJM-94-05X, XJM-93-02X, XJM-93-03X, 2446-02 to -04.
 - (5) Based on samples XJM-93-01X.
 - (6) Detected in 1 out of 12 samples. Not believed to be associated with site activities. (See Subsection 2.2.1)
 - (7) MCL exceedance due to high total suspended solids. Upgradient sample also exceeds MCL.
 - (8) Analytes that exceed primary federal or Massachusetts drinking water standards or CPCs that present cancer risks above 10⁻⁶ or HQs above 1.0 as identified by the baseline risk assessment in the RI Report.
 - (9) Background concentrations determined from unfiltered samples from 10 wells at select locations on base. (Samples analyzed for Total Suspended Solids ranged from <4,000 to 53,000 µg/L)
 - (10) Proposed PRGs for inorganic analytes to be measured using filtered samples.
- EPC = Exposure Point Concentration
ND = Not detected
NA = Not analyzed
MCL = Maximum Contaminant Level(1)
SMCL = Secondary MCL(1) based on aesthetics
HQ = Hazard Quotient
MMCL = Massachusetts Maximum Contaminant Level(2)

TABLE 2-2
PROPOSED PRELIMINARY REMEDIATION GOALS
FOR DOWNGRADE AREA GROUNDWATER
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

CHEMICAL OF POTENTIAL CONCERN ⁽¹⁾	DOWNGRADE AREA GROUNDWATER ⁽³⁾				UPGRADE AREA GROUNDWATER ⁽⁴⁾				BKGRND ⁽⁹⁾ (µg/L)	SMCL (µg/L)	ARARs		PROPOSED PRG (µg/L) ⁽⁷⁾
	AVERAGE EPC (µg/L)		MAXIMUM EPC (µg/L)		AVERAGE EPC (µg/L)		MAXIMUM EPC (µg/L)				MCL (µg/L)	MMCL (µg/L)	
	UNFILTERED	FILTERED	UNFILTERED	FILTERED	UNFILTERED	FILTERED	UNFILTERED	FILTERED					
INORGANICS													
Arsenic	4	2	11.4	3.73	11.29	ND	21.3	ND	10.5	-	50	50	-(5.8)
Manganese	800	800	2,330	2,750	1,066	67.4	1,670	107	291	50	-	-	291
VOCs													
Benzene	3	NA	20	NA	ND	NA	ND	NA	ND	-	5	5	5
Cabron Tetrachloride	0.7	NA	3.3	NA	ND	NA	ND	NA	ND	-	5	5	-(8)

Notes:

- (1) "Drinking Water Regulations and Health Advisories", May 1995, USEPA Office of Water
 - (2) "Drinking Water Standards & Guidelines for Chemicals in Massachusetts Drinking Waters", Autumn 1994, Massachusetts Department of Environmental Protection
 - (3) Based on samples XJM-94-7X to -10X.
 - (4) Based on samples XJM-93-01X.
 - (5) Unfiltered upgradient concentrations greater than downgradient concentrations.
 - (6) Analytes that exceed primary federal or Massachusetts drinking water standards or CPCs that present cancer risks above 10⁻⁶ or HQs above 1.0 as identified by the baseline risk assessment in the RI Report.
 - (7) Proposed PRGs for inorganic analytes to be measured using filtered samples.
 - (8) No ARAR exceeded.
 - (9) Background concentrations determined from unfiltered samples from 10 wells at select locations on base. (Samples analyzed for Total Suspended Solids ranged from <4,000 to 53,000 µg/L.)
- EPC = Exposure Point Concentration
ND = Not detected
NA = Not analyzed
MCL = Maximum Contaminant Level⁽¹⁾
SMCL = Secondary MCL⁽¹⁾ based on aesthetics
HQ = Hazard Quotient
MMCL = Massachusetts Maximum Contaminant Level⁽²⁾

TABLE 2-3
WATER QUALITY PARAMETERS⁽¹⁾
FOR GROUNDWATER
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

PARAMETER ⁽²⁾	UPGRADIENT	SOURCE	PERIMETER	DOWNGRADIENT ($<5\text{PPB BENZENE}$)
Alkalinity	130,000	233,900	156,666	117,500
Nitrate ⁽³⁾	116	58	542	31.5
Nitrogen ⁽⁴⁾	809	525	462	142
TDS	-	-	-	-
Hardness	153,000	210,300	161,200	147,900
Chloride	13,750	25,580	32,243	29,755
Phosphate	955	789	300	111
Sulfate	14,500	16,600	32,833	8,625
pH	7.18	7.35	7.33	7.21
ORP (mV)	109	-28	129	163

Notes:

(1) Averaged values from:

Upgradient Area (XJM-93-01X)

Source Area (XJM-94-05X, XJM-93-03X, 2446-02 to 2446-04)

Perimeter Area (XJM-93-02X, XJM-94-04X, and XJM-94-06X)

Downgradient Area (XJM-94-07X to -10X)

(2) Units for all parameters (except pH and ORP) are in micrograms/Liter

(3) Nitrite, nitrate-nonspecific

(4) By Kjeldahl Method

TABLE 2-4
REMEDIAL ACTION OBJECTIVES
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AOC 43J GROUNDWATER	
	<ul style="list-style-type: none">• Protect potential commercial/industrial receptors located on Army Reserve Enclave property from exposure to groundwater having chemicals in excess of the following PRGs: arsenic (50 µg/L), iron (9,100 µg/L), manganese (291 µg/L), benzene (5 µg/L), ethylbenzene (700 µg/L), toluene (1,000 µg/L), and carbon tetrachloride (5 µg/L).
	<ul style="list-style-type: none">• Protect potential commercial/industrial receptors located off Army Reserve Enclave property from exposure to groundwater having chemicals in excess of the above PRGs.
AOC 43J SUBSURFACE SOILS	
	<ul style="list-style-type: none">• Minimize the possibility of soils contributing to groundwater contamination in excess of the above PRGs.

**TABLE 2-5
POTENTIAL REMEDIAL TECHNOLOGIES
AND PROCESS OPTIONS FOR GROUNDWATER
AOC 43J**

**FEASIBILITY STUDY REPORT
FORT DEVENS, MA**

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION
No Action	None	Not Applicable
Limited Action	Institutional Controls	Zoning Restrictions Deed Restrictions
	Environmental Monitoring	Groundwater Monitoring
Containment	Hydraulic Barriers	Slurry Wall Sheet Piling
Collection	Extraction	Interceptor Trenches Extraction Wells
Treatment	Physical/Chemical	Air Stripping UV Oxidation Activated Carbon Air Sparging (In situ) Bioremediation (Ex situ) Bioremediation (In situ) Fort Devens WWTP Ayer POTW
Discharge	On Site	Fort Devens WWTP To Groundwater
	Off Site	To Surface Water Ayer POTW

Notes:

WWTP = wastewater treatment plant
POTW = publicly owned treatment works
USEPA = U.S. Environmental Protection Agency

TABLE 2-6
POTENTIAL REMEDIAL TECHNOLOGIES
AND PROCESS OPTIONS FOR SOILS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION
No Action	None	Not Applicable
Removal	Excavation	Excavator/Backhoe
Treatment	Physical/Chemical	Incineration
		Thermal Desorption
		Soil Vapor Extraction
		Asphalt Batching
Disposal	On Site	Landfilling
	Off Site	TSD Facility

Notes:

TSD = treatment, storage, and disposal
USEPA = U.S. Environmental Protection Agency

TABLE 2-7
DESCRIPTION OF GROUNDWATER PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/TECHNOLOGY	DESCRIPTION OF PROCESS OPTIONS
<u>No Action</u> None	No action taken to reduce risk.
<u>Limited Action</u> Institutional Controls Environmental Monitoring	<p><u>Zoning Restrictions.</u> Through administrative controls, zone downgradient land off Army Reserve Enclave property to prohibit residential development.</p> <p><u>Deed Restrictions.</u> Place deed restrictions on downgradient land off Army Reserve Enclave property to prohibit future installation of drinking water wells.</p> <p><u>Groundwater Monitoring.</u> Perform water quality analyses to monitor contaminant concentrations and assess future environmental impacts.</p>
<u>Containment</u> Hydraulic Barriers	<p><u>Slurry Wall.</u> Excavate a trench in overburden and fill with impervious backfill to provide a low-permeability cutoff wall.</p> <p><u>Sheet Piling.</u> Drive steel sheet piles into the overburden to provide a low-permeability cutoff wall.</p>
<u>Collection</u> Extraction	<p><u>Interceptor Trenches.</u> Trenches, drains, and piping used to passively collect (by gravity flow) groundwater. Trench installation is typically not used below the bedrock surface.</p> <p><u>Extraction Wells.</u> Install extraction wells to collect groundwater. Wells are typically installed using augers in unconsolidated soils, and coring for bedrock wells. Wells are usually completed by placing a well screen to the desired depth and placing sandpack between well screen and aquifer materials. Well screens are chosen based on the characteristics of the aquifer material in which the well is placed.</p>

TABLE 2-7
DESCRIPTION OF GROUNDWATER PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT FORT DEVENS, MA

GENERAL RESPONSE ACTION/TECHNOLOGY	DESCRIPTION OF PROCESS OPTIONS
	<p><u>Fort Devens WWTP.</u> Transport untreated groundwater to Fort Devens WWTP for treatment. This plant is a primary wastewater treatment facility located on North Post.</p> <p><u>Ayer POTW.</u> Transport untreated groundwater to Ayer POTW for Treatment. This plant is an activated sludge facility.</p>
<p><u>Discharge</u></p> <p>On Site</p> <p>Off Site</p> <p>Off Site</p>	<p><u>Fort Devens WWTP.</u> Transport treated groundwater to Fort Devens WWTP.</p> <p><u>To Groundwater.</u> Reinject treated groundwater meeting Massachusetts discharge limits outside limits of contamination.</p> <p><u>Surface Water.</u> Discharge treated groundwater meeting NPDES permit limits into a surface water such as the Nashua River.</p> <p><u>Ayer POTW.</u> Transport treated groundwater to Ayer POTW.</p>

Notes:

VOGs = volatile organic compounds
UV = ultraviolet
WWTP = waste water treatment plant
POTW = publicly-owned treatment works

TABLE 2-8
DESCRIPTION OF SOILS PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/TECHNOLOGY	DESCRIPTION OF PROCESS OPTIONS
<u>No Action</u> None	No action taken to reduce exposure to site soils.
<u>Removal</u> Excavation	<u>Soil Excavation.</u> Excavate contaminated soils in highest concentration of BTEX from over the groundwater plume. Contaminated soils would be removed by conventional excavation equipment.
<u>Treatment</u> Physical/Chemical	<p><u>Incineration.</u> Transport excavated soils to an off-site facility for thermal destruction of organic contaminants.</p> <p><u>Thermal Desorption.</u> Process excavated soils through an on-site or off-site thermal desorption unit. Thermal desorption uses indirect or direct heat exchange to vaporize organic contaminants including VOCs and some SVOCs from soil.</p> <p><u>Soil Vapor Extraction (SVE)/Bioventing.</u> Remediate BTEX contaminated soils below the pavement by extracting gases from the soil using SVE wells/piping and vacuum pumps and passing the gases through GAC or thermal/catalytic oxidizers for treatment. Flow of atmospheric air through the soil also enhances biological degradation of hydrocarbon contaminants (bioventing).</p> <p><u>Asphalt Batching.</u> Mix excavated soils with an asphalt emulsion and other additives to make a pavement road base material. Asphalt batching immobilizes the petroleum contaminants within the soil-asphalt mix.</p>
<u>Disposal</u> On Site Off Site	<p><u>Landfilling.</u> Dispose of petroleum contaminated soils that meet allowable contaminant levels in the Fort Devens consolidation landfill.</p> <p><u>TSD Facility.</u> Transport contaminated soils to an off-site treatment facility permitted for petroleum (including used waste oil) contaminated soils.</p>

Notes:

VOCs = volatile organic compounds
 SVOCs = semivolatile organic compounds
 GAC = Granulated Activated Carbon
 RCRA = Resource Conservation and Recovery Act
 TSD = treatment, storage and disposal

TABLE 2-9
SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
<u>No Action</u> None	None Easily implementable	None.	Retained.	Required for consideration by NCP. Does not achieve remedial action objectives.
<u>Limited Action</u> Zoning Restrictions	Would prohibit residential development within groundwater plume area if off the Army Enclave property. Would require negotiations with property owners downgradient.	Contamination may have migrated downgradient of the Army Reserve Enclave property boundary.	Retained.	
Deed Restrictions	Would prohibit installation of groundwater wells within groundwater plume area if off the Army Enclave property. Would require negotiations with property owners downgradient.	Contamination may have migrated downgradient of the Army Reserve Enclave property boundary.	Retained.	
Groundwater Monitoring	None. Easily implementable. Groundwater monitoring wells currently exist on site and may be used in a groundwater monitoring program.	None. Would enable assessment of changes in contaminant concentrations over time.	Retained.	May be considered in conjunction with other technologies.

continued

TABLE 2-9
SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
<u>Containment</u> Slurry Wall Sheet Piling	Hydraulic barrier could have unpredictable impacts on site groundwater flow out from the bedrock and within vertical gradients. Generally used in conjunction with capping. Implementable. Compared to slurry wall, less controlled installation, less likely to achieve low permeability seal due to poor connections between the steel sheets. Similar unpredictable hydraulic impacts as the slurry wall.	Barrier design would require consideration of groundwater contaminants that may degrade barrier over time. May reduce mobility of chemicals in groundwater. Similar effectiveness as slurry wall.	Eliminated. Eliminated.	Hydraulic barrier may contain groundwater contaminants but may also have unpredictable impacts on site groundwater flow out from the bedrock and within vertical gradients. Similar unpredictable hydraulic impacts as the slurry wall.
	<u>Collection</u> Interceptor Trenches	Implementable. May improve collection capabilities within low-permeable soils at AOC 43J. Difficult to install in areas where groundwater is within bedrock.	Retained.	A trench could be strategically located across the area of highest contamination to stop further migration.

continued

TABLE 2-9
SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
Extraction Wells	None. Implementable. Commonly used technology. Produces very little contaminated soil requiring disposal. Can be installed where groundwater is within bedrock.	None. Effective mechanism to collect contaminated groundwater. Can prevent migration of contaminated groundwater.	Retained.	Several wells would have to be strategically located so that the cones of depression intersect and capture groundwater flow. Could be used in conjunction with interceptor trenches.

continued

TABLE 2-9
SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
<u>Treatment</u> Air Stripping	None. Easily implementable commonly used technology.	None. Provides effective treatment for VOCs. Special disposal or destruction required for off-gas collection.	Eliminated.	Can not effectively treat some toxic SVOCs to "health advisory" levels (ie; naphthalene) which is required for discharge to the Fort Devens WWTP.
UV Oxidation	None. Commonly used technology. Self-contained and mobile units available.	Provides effective treatment for organics contaminants of concern. Contaminants are destroyed.	Retained.	
Activated Carbon	None. Implementable. Commonly used technology. Self contained and mobile units available.	Provides effective treatment for VOCs and other organics. Contaminants are adsorbed. Waste carbon considerably more toxic than influent water, special disposal, regeneration or destruction is required.	Retained.	

continued

TABLE 2-9
SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
Air Sparging (In situ)	Does not require groundwater extraction. An emerging technology. The low-permeable soil at AOC 43J will potentially impact effectiveness of bubbling air in the water column.	Effective for treatment of VOCs but difficulties can arise in controlling and collecting off gases at the site.	Eliminated.	
Bio-remediation (Ex situ)	None. An emerging groundwater treatment technology.	Volatiles must be contained. BTEX best removed under aerobic conditions and carbon tetrachloride is removed under anaerobic conditions making simultaneous treatment difficult. A pilot scale test is recommended prior to design and carbon polishing may be needed.	Eliminated.	

continued

TABLE 2-9
SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
Bio-remediation (In situ)	Biodegradation of organic contaminants may be naturally occurring under anaerobic conditions. Oxygenating groundwater plume for aerobic conditions is impractical due to potential mounding, impacts on groundwater flow and fouling of injection points from high concentrations of iron and manganese.	None. Biological treatment will remove BTEX and carbon tetrachloride.	Retained.	
Fort Devens WWTP	Would require piping groundwater to existing Fort Devens sewer system.	Fort Devens has a primary wastewater treatment facility, not designed to treat toxic contaminants.	Eliminated.	
Ayer POTW	Would require piping or trucking groundwater to Ayer sewer system.	Untreated groundwater would not meet pretreatment standards for total toxic organics (1 mg/l).	Eliminated.	

continued

TABLE 2-9
SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
<u>Discharge</u> Fort Devens WWTP	Would require piping groundwater to existing Fort Devens sewer system. Facility currently has a notice of non-compliance. However, a Wastewater Discharge Management Plan and O&M Manual are being prepared in anticipation of future industrial discharges to the facility.	Fort Devens has a primary wastewater treatment facility which is not designed to treat inorganics and BTEX. Groundwater would need treating to meet proposed industrial pretreatment requirements.	Retained.	Does not permit discharge of any toxic pollutants (SVOCs) that exceed health advisories. This excludes air stripping as a possible treatment option.
To Groundwater	Limited by recharge/permeability rates of soils and availability of suitable nearby discharge site. Reinjection wells or trench would likely foul due to high concentrations of Fe and Mn. On-site discharge would reduce administrative burden of obtaining discharge permit.	None, as long as water has been treated to acceptable discharge standards.	Eliminated.	No major advantage over discharge to Fort Devens WWTP.

continued

TABLE 2-9
SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
Ayer POTW	Would require piping or trucking groundwater to Ayer sewer system.	Groundwater would also need to be treated to acceptable discharge standards (total toxic organics).	Eliminated.	Discharge to the Ayer POTW offers no significant advantage over discharge to the Fort Devens WWTP. Both alternatives require pretreatment. The Ayer POTW option requires greater capital investment for piping or O&M for trucking.
Surface Water	NPDES permit required for off-site discharge. Requires considerable piping to a major surface water body (Cold Spring Brook, Robbins Pond, Nashua River). Negative public perception.	None. If contaminants are treated to acceptable limits.	Eliminated.	

Notes:

= National Contingency Plan
 = maximum contaminant levels
 = waste water treatment plant
 = publicly owned treatment works
 = National Pollutant Discharge Elimination System
 = Resource Conservation and Recovery Act
 = treatment, storage and disposal
 = ultraviolet

TABLE 2-10
SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
<u>No Action</u> None	None.	Does not reduce toxicity, mobility, or volume of contaminants in soil.	Retained.	Required for consideration by NCP. Does not meet remedial response objectives.
<u>Removal</u> Excavation	None.	Soil contaminant levels are in equilibrium with groundwater contaminant levels. Soil removal will provide little benefit. Backfilled soil will become recontaminated in contact with groundwater.	Eliminated.	Although eliminated as a removal action for ex situ treatment of site soils, excavation may be required to install in situ remedial systems.

TABLE 2-10
SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
<u>Treatment</u> Incineration	Easily implementable, off-site facilities on-line.	Effective treatment for organics.	Eliminated.	All ex-situ soil treatment options are eliminated due to the minimal benefit associated with soil removal (see excavation).
	Permit requirements must be considered. Need to assess availability of utilities. Technology is readily implementable.	Proven effective for Petroleum contaminated soils. Less effective for high moisture content material which will be present at depths close to the water table where contaminant concentrations are the highest.	Eliminated.	All ex-situ soil treatment options are eliminated due to the minimal benefit associated with soil removal (see excavation).
Thermal Desorption				

continued

TABLE 2-10
SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
Soil Vapor Extraction/ Bioventing (In situ)	Easily implementable. System design will need to consider effects of low-permeable site soils.	SVE proven effective for BTEX removal. Bioventing may further remove less volatile fractions.	Retained	
	Venting would be done in conjunction with groundwater extraction and treatment to remediate the two media simultaneously.	Potential short-circuiting of air can leave some untreated areas.		
Asphalt Batching	Readily implementable. Has been used for similar remedial efforts at Fort Devens. Site soils may require the addition of aggregate to make an acceptable road-base material.	Effectively immobilizes petroleum contaminants within the pavement mix.	Eliminated.	All ex-situ soil treatment options are eliminated due to the minimal benefit associated with soil removal (see excavation).

continued

TABLE 2-10
SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/ PROCESS OPTION	APPLICABILITY TO		SCREENING STATUS	COMMENTS
	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS		
<u>Disposal</u> Fort Devens Consolidation Landfill	Space requirements on site must be evaluated. Facility must comply with Massachusetts landfill regulations.	Concentrations of VOCs in extreme hot spot areas may exceed allowable contaminant levels for soil reuse at lined landfills requiring frequent soil screening and soil segregation.	Retained for soil removal required to install in situ remedial systems.	
TSD Facility	Implementable.	Many vendors provide treatment/disposal /recycling of petroleum contaminated soils. Must comply with Land Disposal Restrictions.	Retained for soil removal required to install in situ remedial systems.	

Notes:

NCP = National Contingency Plan
TSD = treatment, storage, and disposal

TABLE 2-11
SCREENING SUMMARY OF TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/PROCESS OPTION	RETAINED	ELIMINATED
GROUNDWATER		
<u>No Action</u>		
None	X	
<u>Limited Action</u>		
Zoning Restrictions	X	
Deed Restrictions	X	
Groundwater Monitoring	X	
<u>Containment</u>		
Slurry Wall		X
Sheet Piling		X
<u>Collection</u>		
Interceptor Trenches	X	
Extraction Wells	X	
<u>Treatment</u>		
Air Stripping		X
UV Oxidation		X ⁽¹⁾
Activated Carbon	X	
Air Sparging (In situ)		X
Bioremediation (Ex situ)		X
Bioremediation (In situ)	X	
Fort Devens WWTP		X
Ayer POTW		X

TABLE 2-11
SCREENING SUMMARY OF TECHNOLOGIES AND PROCESS OPTIONS
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

GENERAL RESPONSE ACTION/PROCESS OPTION	RETAINED	ELIMINATED
<u>Discharge</u>		
Fort Devens WWTP	X	
To Groundwater		X
Surface Water		X
Ayer POTW		X
SOILS		
<u>No Action</u>		
None	X	
<u>Removal</u>		
Excavation		X
<u>Treatment</u>		
Incineration		X
Soil Vapor Extraction/Bioventing (In situ)	X	
Asphalt Batching		X
Thermal Desorption		X
<u>Disposal</u>		
Fort Devens Consolidation Landfill	X	
TSD Facility	X	

Notes:

UV = ultraviolet
 WWTP = wastewater treatment plant
 POTW = publicly owned treatment works
 TSD = treatment, storage and disposal

⁽¹⁾ Although UV oxidation is effective and implementable, it was eliminated based on higher cost relative to activated carbon (see Subsection 2.7).

3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

In this section, technically feasible process options retained following the screening described in Section 2.0 are combined to form remedial action alternatives. Alternatives are developed to attain the remedial action objectives discussed in Section 2.0, using the following General Response Actions either singly or in combination: (1) No Action; (2) Limited Action; (3) Containment; (4) Treatment; (5) Discharge/Disposal.

The developed remedial alternatives are then screened with respect to the criteria of effectiveness, implementability, and cost to meet the requirements of CERCLA and the National Contingency Plan (NCP). The objective of this screening step is to eliminate impractical alternatives or higher cost alternatives (i.e., order of magnitude cost differences) that provide little or no improvement in effectiveness or implementability over their lower cost counterparts.

3.1 DEVELOPMENT OF ALTERNATIVES

Five remedial alternatives were developed for AOC 43J to address remedial action objectives presented in Section 2.0. In assembling these alternatives, general response actions and process options chosen to represent the various technology types for the medium of concern are combined to form alternatives for the site as a whole. Alternatives were developed to provide a range of options consistent with USEPA RI/FS guidance (USEPA, 1988).

These alternatives include:

- Alternative 1: No Action
- Alternative 2: Intrinsic Bioremediation
- Alternative 3: Intrinsic Bioremediation/Passive In-Situ Bioremedial Containment
- Alternative 4: Intrinsic Bioremediation/Hydraulic Containment

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- Alternative 5: Groundwater Collection and Treatment/Soil Treatment

3.1.1 Alternative 1: No Action

The No Action alternative does not include any remedial action components to reduce or control potential risks at AOC 43J. In addition, existing monitoring would be discontinued. The No Action alternative will not be evaluated according to screening criteria; it will pass through screening to be evaluated during the detailed analysis as a baseline for the other retained alternatives (USEPA, 1988).

3.1.2 Alternative 2: Intrinsic Bioremediation

Key components of Alternative 2 include:

- Intrinsic Bioremediation
- Long-Term Groundwater Monitoring
- 5-Year Site Reviews

Based upon organic and inorganic speciation in the aquifer, it appears that biological degradation of the petroleum hydrocarbons is occurring naturally at AOC 43J. Alternative 2 would allow the natural biological degradation (intrinsic bioremediation) of the CPCs to continue to occur at the site without interruption. To assess the effectiveness of biological degradation at the site, groundwater monitoring would be performed on a scheduled basis. Additional monitoring wells would need to be installed.

The biological degradation of hydrocarbons is essentially an oxidation-reduction reaction in which the hydrocarbon compound is oxidized (donates electrons) and an electron acceptor, such as oxygen, is reduced (accepts electrons). Under aerobic conditions, oxygen is the electron acceptor for biological degradation activity. When oxygen is absent or depleted from a system, anaerobic conditions exist and other compounds are used as electron acceptors. Other compounds that are used as electron acceptors during anaerobic degradation of petroleum hydrocarbons include nitrate, manganese oxides, sulfate, iron, and hydrogen.

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The electron acceptor that is ultimately used in the anaerobic biodegradation of hydrocarbons depends upon compound concentrations, availability, and the oxidation-reduction conditions of the aquifer. The order in which electron acceptors are used in anaerobic biodegradation (according to free energy laws) is as follows: oxygen (aerobic conditions), nitrate, manganese oxides, ferric iron (FeIII), sulfate, and hydrogen (methanogenic conditions). As the progression of electron acceptor use occurs through this sequence, the ORP of the aquifer decreases.

As defined by name, compounds that act as electron acceptors in anaerobic biodegradation gain electrons and are reduced. Typical examples of reduced forms of compounds that are produced during anaerobic biodegradation of hydrocarbons include nitrite from nitrate, manganese as Mn[II] from Mn[IV], ferrous (Fe[II]) iron from ferric ([Fe(III)]) iron, sulfide compounds from sulfate reduction, and methane from hydrogen reduction. The presence of these reduced forms of compounds in an aquifer is an indicator that biological activity is occurring. Inorganic speciation can be used to model anaerobic biological degradation.

Table 2-3 presents the groundwater inorganic speciation data for groundwater monitoring wells upgradient of the source, at the source area, at the perimeter, and downgradient (where benzene concentrations are less than 5 $\mu\text{g/L}$). Data included in this table include nitrite/nitrate concentrations, sulfate concentrations, phosphate concentrations, and ORP. Based on several speciation trends presented in this table, it appears that anaerobic activity is occurring in the zone of contamination. These trends include a) decreased average nitrate/nitrite concentrations in the contaminated region, b) decreased sulfate concentrations in the aquifer, c) decreased ORP measurements in the source area, and d) decreased total nitrogen and phosphate concentrations in the aquifer. Decreased nitrate and sulfate concentrations in the plume area (compared to up- and down-gradient concentrations), indicate that microbial-induced oxidation reduction processes are occurring at AOC 43J. This assumption is confirmed with ORP data which indicates that the ORP is negative in the contaminated zone and is less than the ORP found in surrounding groundwater. Decreasing nutrient concentrations (total nitrogen and phosphate concentrations) also affirm the premise that active microbiological degradation of the CPCs is occurring in the zone of contamination, as these compounds are consumed (uptake) within the contaminated groundwater.

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Intrinsic bioremediation would continue at AOC 43J until the remedial action objectives are achieved. Calculations based upon degradation rates from literature indicate that contaminants would not migrate off Army Reserve Enclave property. Details of these calculations are discussed in Section 4.0. Pilot testing and/or additional sampling rounds would be required as part of the design to confirm degradation rates and refine long-term groundwater monitoring needs.

Long-term groundwater monitoring would also be instituted to monitor organic and soluble inorganic CPCs. Five-year site reviews would be conducted to evaluate whether the alternative continues to protect human health and the environment. Details of the monitoring and site reviews will be discussed in Section 4.0.

3.1.3 Alternative 3: Intrinsic Bioremediation/Passive In-Situ Bioremedial Containment

Key components of Alternative 3 include:

- Intrinsic Bioremediation
- Passive In-Situ Bioremedial Containment System Installed Downgradient
- Long-Term Groundwater Monitoring
- 5-Year Site Reviews

Alternative 3 involves permitting natural biological degradation of the CPCs to continue to occur on site and placing of a passive system to deliver oxygen and mineral nutrients to the aquifer downgradient. The objective of passive in-situ bioremediation is to promote the biological degradation of the dissolved (downgradient) portion of the contamination plume without withdrawing or injecting groundwater. In-situ biological remediation of the CPCs brought about through the passive introduction of oxygen and nutrients will result in the destruction of the CPCs and will prevent further (off-site) migration of the contamination plume.

Data presented in Table 2-3 infers that anaerobic biological degradation of the fuel is occurring on site. Detail on the anaerobic biological degradation of the CPCs (intrinsic bioremediation) is presented in Alternative 2. In general, biological degradation of the VOCs associated with gasoline is achieved more

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readily under aerobic conditions than under anaerobic conditions, especially for benzene. Anaerobic biological degradation is occurring currently at AOC 43J. Aerobic biological treatment by aerating the entire groundwater plume would be impractical to achieve for several reasons. Because of low groundwater velocity (approximately 37 feet per year) and the low solubility of oxygen in water, many oxygenated water injection trenches or biosparging points would be required to effectively distribute the oxygen throughout the contaminated area. Other issues include the potential for groundwater mounding, the possible effects on existing vertical and horizontal groundwater gradients at the site, and likely fouling of injection points/trenches because of high concentrations of iron and manganese in the groundwater. However, oxygen can be passively introduced to the aquifer to promote aerobic conditions to enhance biological degradation at a faster rate near the plume edge minimizing the potential of plume migration off-site.

The passive introduction of oxygen to the aquifer would be accomplished using metal peroxides. Solid metal (magnesium) peroxides, in the form of briquettes or 'pencils' would be inserted into 2-inch diameter passive bioremediation wells screened in the contaminated region of the aquifer. As groundwater passes through the well formations, the metal peroxides will slowly dissolve into the water and release oxygen. This oxygen will be available subsequently for aerobic biological degradation. Water and other inert byproducts (e.g., magnesium hydroxide) would also be formed from the metal peroxide dissolution. Nutrients to enhance biodegradation would also be added as needed.

To accomplish passive aerobic biological degradation at AOC 43J, it is estimated that up to 20 passive bioremediation wells would be needed at the site. The well system would be comprised of 2-inch diameter polyvinyl chloride (PVC) wells spaced on 10-foot centers, screened from 12 to 22 feet bgs (10 - 20 slot screens). Removable wire screens or fabric 'socks' would be used to hold the solid metal peroxides.

Operation and maintenance of the passive in-situ bioremediation system would consist of a) monitoring groundwater for dissolved oxygen and mineral nutrients in addition to the parameters required for long-term groundwater monitoring, b) replacing oxygen release and mineral nutrient material in the passive bioremediation wells, and c) providing well cleaning services (e.g., acid treatment and surge block pumping of the wells) to relieve potential clogging of the well screens caused by microorganism growth and/or precipitate formation.

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Passive bioremediation would continue at AOC 43J until the remedial action objectives for the CPCs were obtained. This alternative would also include long-term groundwater monitoring, and five-year site reviews as discussed in Alternative 2.

3.1.4 Alternative 4: Intrinsic Bioremediation/Hydraulic Containment

Key components of Alternative 4 include:

- Intrinsic Bioremediation
- Hydraulic Containment System (Pump and Treat)
- Discharge of Treated Effluent to the Fort Devens Waste Water Treatment Facility (WWTF)
- Long-Term Groundwater Monitoring
- 5-Year Site Reviews

Alternative 4 involves permitting natural biological degradation of the CPCs to continue to occur on site and involves placement of vertical groundwater extraction wells and installation of aboveground groundwater treatment equipment. The objective of the groundwater extraction is to halt the migration of the contaminant plume (hydraulic containment). Wells also would be positioned within the most contaminated portion of the plume to maximize treatment efficiency.

Groundwater extraction would be achieved using vertical extraction wells. The type of groundwater extraction well used at a site ultimately depends upon soil characteristics such as soil permeability, aquifer characteristics such as hydraulic gradient and depth to groundwater, and feasibility/cost. To determine more accurately which groundwater extraction system would be more appropriate at AOC 43J, a groundwater capture modeling program was used. This model utilizes soil and aquifer characteristics and other information (e.g., number and location of groundwater extraction wells) to predict what the resulting effects upon the aquifer would be.

Based upon results from the groundwater capture modeling program (presented in detail in Appendix B), a three vertical well groundwater extraction system is recommended for AOC 43J. This groundwater extraction system would consist of three 6-inch diameter PVC vertical groundwater extraction wells screened from

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approximately 12 to 22 feet bgs and arranged within the central plume area. A groundwater extraction rate of approximately 1 gpm would be required in order to provide hydraulic control of the site (Appendix B). At a groundwater extraction rate of 1 gpm, the groundwater table is estimated to be lowered approximately 1 foot.

Groundwater extracted from the aquifer would be treated in a liquid phase GAC treatment system and the treated effluent would be discharged to the Fort Devens WWTF. A description of the process option is discussed in Section 2. Operation and maintenance of the groundwater pump and treat system would consist of monitoring groundwater for CPC concentrations and maintaining groundwater extraction and treatment system equipment.

Intrinsic bioremediation monitoring and groundwater extraction would continue at AOC 43J until the remedial action objectives for the CPCs were obtained. This alternative would also include long-term groundwater monitoring and five-year site reviews as discussed in Alternative 2.

3.1.5 Alternative 5: Groundwater Collection and Treatment/Soil Treatment

Key components of Alternative 5 include:

- Groundwater Treatment
- Soil Vapor Extraction (SVE)
- Discharge of Treated Effluent to the Fort Devens WWTF
- Long-Term Groundwater Monitoring
- 5-Year Site Reviews

Alternative 5 involves placement of vertical groundwater extraction wells, installation of aboveground groundwater treatment equipment, placement of vertical soil vent wells for SVE, and installation of aboveground soil gas treatment equipment. The objectives of groundwater extraction and treatment are a) to halt/minimize the migration of the contamination plume (hydraulic control), b) to remediate the aquifer, and c) to lower the groundwater table to allow more effective SVE treatment of the vadose zone. The objective of soil venting is to remediate the vadose zone and to prevent further contamination of the aquifer. The combination of groundwater pump and treat and SVE will halt/minimize off-

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site migration of groundwater contaminants and provide remediation to site soil and groundwater.

Groundwater extraction and treatment would be achieved using the same flow rates and arrangement as detailed in Alternative 4.

Soil venting will prevent future contamination of the aquifer because it will address the soil that contains VOCs in equilibrium with groundwater. These soils will be exposed when the groundwater table is lowered through groundwater extraction. Additional removal of VOCs will occur when the groundwater table is lowered further through seasonal fluctuations.

Based upon an estimated contaminated vadose zone soil volume of 400 cubic yards (75 feet by 140 feet by 1 foot deep [average drawdown estimate in most contaminated region as a result of groundwater extraction]) and an average soil BTEX concentration of 25 $\mu\text{g/g}$ BTEX, a total mass of 13 kilograms (kg) BTEX exists in the soil amenable to SVE (Table A-1). Removal of the CPCs through SVE would prevent them from re-entering the groundwater.

To gather full-scale SVE design information for a particular site, an on-site (intrinsic or air) permeability test is required. Initial estimates of soil permeability at AOC 43J calculated from hydraulic conductivity information (7.3×10^9 centimeters squared [cm^2]) indicate that the soil at AOC 43J may be somewhat difficult to aerate. For design purposes, an in-situ soil permeability test would be required to further refine variables, as actual vadose zone conditions may not be reflected through hydraulic conductivity testing of the aquifer.

Because a permeability test has not been conducted at AOC 43J, air permeability data gathered from AOC 43G was applied to the AOC 43J location for estimation purposes. Flow conditions observed at AOC 43G that were assumed for AOC 43J include a radius of influence of 23 feet (defined by 0.1" water column [w.c.] vacuum) and a soil venting flow rate of 1.8 standard cubic feet per minute (scfm) per foot of screened interval at a vacuum of 30 inches of water column (30" w.c.) Using this SVE data, horizontal vent wells, vertical vent wells, or both could be utilized to treat the vadose zone of the plume area at AOC 43J. Based upon this limited SVE information and the fact that placement of horizontal vent wells would be difficult because of a fluctuating groundwater table in the area, vertical vent wells are recommended for soil venting at AOC 43J.

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This soil venting system would consist of approximately nine 2-inch PVC vertical vent wells screened for the zone of contamination and arranged within the central plume area. A total extraction flow rate of 54 to 90 scfm would be required to vent this site (6 to 10 scfm per vent well). Final SVE system design would be determined from on-site permeability testing data.

Because oxygen would move through the contaminated vadose zone as a result of soil vapor movement, aerobic biological degradation is expected to occur in the vadose zone soils of AOC 43J due the SVE activity. Contaminants that would be susceptible to aerobic biological degradation would include volatile and non-volatile petroleum hydrocarbons. The additional removal of the contaminants through biological degradation would decrease the amount of vadose zone treatment time. The only contaminant that would be unaffected by aerobic biological degradation would be carbon tetrachloride, which would be removed during the SVE process.

Extracted soil vapor would require treatment before discharge to the atmosphere. Based on soil vapor flow and make-up, vapor phase activated carbon is recommended for treatment of soil vapor extracted from AOC 43J.

Operation and maintenance of the soil vent system would consist of monitoring soil gas for VOC concentrations, maintaining SVE and treatment system equipment and replacing activated carbon.

Groundwater pump and treat and soil venting would continue at AOC 43J until the remedial action objectives for the CPCs were obtained. This alternative would also include long-term groundwater monitoring, and five-year site reviews discussed under Alternative 2.

3.2 SCREENING OF ALTERNATIVES

In this subsection, the alternatives are screened with respect to the criteria of effectiveness, implementability, and cost to meet the requirements of CERCLA and the NCP. The three criteria used for screening the alternatives are as follows:

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Effectiveness: Each alternative was judged for its ability to effectively protect human health by reducing the toxicity, mobility, or volume of contaminants; both short- and long-term effectiveness were evaluated. Short-term effectiveness involves reducing existing risks to the community and workers during the construction and implementation period, identifying expected effects to the environment and potential mitigative measures during construction and implementation, the alternative's ability to meet remedial action objectives, and the time frame required to achieve remedial action objectives. Long-term effectiveness, which applies after remedial action objectives have been attained, considers the magnitude of the remaining residual risk because of untreated wastes and waste residuals, and the adequacy and reliability of specific technical components and control measures.

Implementability. Each alternative was evaluated in terms of technical and administrative feasibility. In the assessment of short-term technical feasibility, availability of a technology for construction or mobilization and operation, the availability of required services and trained specialists or operators, as well as compliance with action-specific ARARs during the remedial action were considered. Long-term technical feasibility considered the ease of operation and maintenance (O&M), technical reliability, ease of undertaking additional remedial actions, and monitoring of technical controls of residuals and untreated wastes. Administrative feasibility for implementing a given technology addressed coordination with other agencies.

Cost. The final criterion for initial screening of alternatives is the cost associated with the given remedy. Absolute accuracy in cost estimates during screening is not essential. The focus should be to make comparative estimates for alternatives with relative accuracy so that cost decisions among alternatives will be sustained as the accuracy of cost estimates improves beyond screening (USEPA, 1988). Relative capital and O&M costs are discussed at this stage, as well as factors influencing cost sensitivity. Potential liability associated with untreated waste and treatment residuals is also discussed. Cost estimates for alternatives screening are based on generic unit costs, vendor information, cost-estimating guides, and prior similar estimates. Cost estimates for items common to all alternatives or indirect costs do not normally warrant substantial effort during the alternative screening phase.

Alternative Evaluation. For each alternative, a matrix was developed highlighting the alternative's advantages and disadvantages with respect to effectiveness, implementability, and cost. The alternative evaluation matrix presents a clear, concise procedure for screening potential remedial action alternatives. Based on this matrix, a decision was made to either retain the alternative for detailed analysis or eliminate it from further consideration. Screening matrices for each alternative are presented in Tables 3-1 through 3-4. Table 3-5 provides a summary of the alternatives screening process.

3.2.1 Alternative 2: Intrinsic Bioremediation

This alternative consists of installing additional groundwater monitoring wells and monitoring the natural biodegradation process. Monitoring would also be performed to assess the concentration and position of the plume in relation to the Army Reserve Enclave boundary. Existing groundwater analytical results indicate that anaerobic biological degradation of the CPCs is already occurring at AOC 43J. Intrinsic bioremediation, therefore, consists of allowing the natural biological degradation of the CPCs to continue to occur at the site without interruption. To assess the effectiveness of biological degradation at the site, groundwater monitoring is conducted as part of an intrinsic bioremediation program.

Effectiveness. In the anaerobic microbial degradation process of intrinsic bioremediation, the organic CPCs are ultimately converted to inert compounds such as carbon dioxide, methane, and water. Because of this process, intrinsic bioremediation will effectively reduce the toxicity and volume of the VOCs of concern in the site groundwater. As a result, downgradient or off-site migration of site contaminants will be minimized. Additionally, removal of the organics will return the groundwater quality to upgradient conditions resulting in a return of the more insoluble forms of arsenic, iron and manganese.

The time required to remediate the groundwater at AOC 43J using intrinsic bioremediation can be estimated using the first order degradation rate equation:

$$C = C_0 e^{-kt}, \text{ where}$$

C is the final concentration to be achieved ($\mu\text{g/L}$),
C₀ is the starting concentration ($\mu\text{g/L}$),
k is the first order decay coefficient (1/day), and

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t is the amount of time required to achieve concentration C (days).

Solute transport calculations were performed for the organic CPCs which are benzene, toluene, ethylbenzene, and carbon tetrachloride (Appendix C). The calculations considered the first order degradation rates (half-lives) for these compounds obtained from a literature search. These calculations are further described in Subsection 4.2.1. Alternative 2 Description. The calculations predict that the organic CPCs will not migrate downgradient of the Army Reserve Enclave boundary. The amount of time to achieve PRGs is within 5 years for toluene, between 5 and 10 years for benzene and carbon tetrachloride, and between 25 and 30 years for ethylbenzene. Assuming all compounds are degraded simultaneously, the intrinsic bioremediation of ethylbenzene will be the controlling process. A time requirement of 27 years is therefore estimated for cleanup of AOC 43J using intrinsic bioremediation for cost estimating purposes.

The potential for short-term worker exposure to contaminated groundwater is considered minimal during intrinsic groundwater monitoring well installation. Further exposure of site workers to site contamination would not exist for intrinsic bioremediation.

Implementability. Because biological degradation is already occurring naturally under existing site conditions, no further implementation is necessary for the intrinsic bioremediation process itself. Additional groundwater monitoring wells are recommended as part of intrinsic bioremediation monitoring however, to provide additional biodegradation information. Local contractors and "off-the-shelf" materials would be available to install the monitoring wells. A long-term monitoring plan would be prepared and submitted for regulatory review and approval. Monitoring would be implemented easily, requiring the use of basic groundwater sampling techniques.

Cost. The cost of implementing Alternative 2 would consist primarily of groundwater monitoring well installation and groundwater monitoring costs.

Conclusion. This alternative will be retained for detailed analysis. Intrinsic bioremediation, combined with long-term groundwater monitoring provides a low-cost approach that would help protect human health.

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3.2.2 Alternative 3: Intrinsic Bioremediation/Passive In-Situ Bioremedial Containment

This alternative consists of intrinsic bioremediation on-site and placement of slow release oxygen release compounds in downgradient passive bioremediation wells. Slow release peroxides would be used to promote the in-situ aerobic biological degradation of the dissolved phase contaminants and prevent off-site migration of benzene, ethylbenzene, and toluene. Carbon tetrachloride, degraded anaerobically, would be treated intrinsically upgradient on site.

Passive biological degradation of organic compounds is a process by which oxygen and mineral nutrients are introduced to an aquifer to promote biological remediation by the naturally occurring soil microorganisms without withdrawing or reinjecting groundwater. Delivery of oxygen and mineral nutrients will be accomplished by placing solid, slow-release metal peroxides in passive bioremediation wells. As groundwater passes through the wells, oxygen and mineral nutrients will dissolve into the groundwater, diffuse into the aquifer, and promote biological degradation of contaminants. Slow release of oxygen will potentially minimize iron and manganese fouling of the passive bioremediation wells.

Effectiveness. In the microbial degradation process brought about by in-situ bioremediation, the organic CPCs are ultimately converted to inert compounds such as carbon dioxide and water (aerobic conditions) and to carbon dioxide and methane (anaerobic conditions). Because of the actual degradation/destruction of the organic contaminants that occurs in this alternative, intrinsic bioremediation and passive in-situ bioremediation will effectively reduce the toxicity and volume of organic contaminants in the site groundwater. As a result, downgradient or off-site migration of site contaminants will be minimized.

Because passive in-situ biological methods are designed for bioremedial containment and only address downgradient contamination (the compounds not degraded upgradient under intrinsic biological conditions), the time required to remediate the groundwater at AOC 43J using intrinsic bioremediation and passive in-situ bioremedial containment will be the same for that of intrinsic bioremediation alone. As indicated in Section 3.2.1, the time to achieve PRGs for the CPCs at AOC 43J using intrinsic bioremediation is estimated to be 27 years.

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There is minimal potential for short-term worker exposure to contaminated groundwater during passive bioremediation well installation. Exposure of site workers to site contamination also would not be extensive during passive bioremediation well amendment maintenance.

Implementability. Prior to full-scale implementation of passive bioremediation, bench-scale and possibly field-scale testing would be required. Passive bioremediation design tests would include a) identification of the most suitable oxygen release compound for the site, b) determination of the effects of iron and manganese precipitation on oxygen diffusion in the aquifer, c) determination of the role of nutrient addition in passive bioremediation, and d) well design information (e.g., well layout requirements). Upon completion of design testing and full-scale design, a passive bioremediation system would be relatively easy to implement. Local contractors and "off-the-shelf" materials would be available to construct the passive bioremediation wells.

Cost. The cost of implementing Alternative 3 would consist primarily of design testing, passive bioremediation well installation, system operation and maintenance, in addition to intrinsic bioremediation expenses which include groundwater monitoring well installations, and groundwater monitoring costs.

Conclusion. This alternative will be retained for detailed analysis because it will prevent off-site migration and treat contaminants on-site.

3.2.3 Alternative 4: Intrinsic Bioremediation/Hydraulic Containment

This alternative consists of installing additional groundwater monitoring wells and monitoring the natural biodegradation process as detailed in Alternative 2. Instead of relying on passive bioremediation wells (Alternative 3) to prevent possible migration of contaminants exceeding the PRGs downgradient, Alternative 4 utilizes a pump and treat system to contain the migration of the contaminant plume.

Effectiveness. Groundwater pump and treat would reduce the mobility and volume of contamination in site groundwater in two ways. First, because of groundwater extraction activity, groundwater pump and treat would effectively halt the migration of contaminated groundwater. Second, groundwater extraction would reduce the overall mass of contamination in the groundwater by removing

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groundwater containing dissolved contamination. Treatment of groundwater would be achieved by liquid phase GAC. Contaminants would be transferred to carbon which would require disposal or regeneration. Intrinsic bioremediation also will effectively reduce the toxicity and volume of organic contaminants in the site groundwater because of the actual degradation/destruction of the organic contaminants that occurs in this technology. In the microbial degradation process brought about by bioremediation, the organic CPCs are ultimately converted to inert compounds such as carbon dioxide and water (aerobic conditions) and to carbon dioxide and methane (anaerobic conditions). As a result, downgradient or off-site migration of site contaminants will be minimized.

Based upon modeling information and soil and contaminant characteristics, it is estimated that approximately 56 years would be required to remove all the contamination in the aquifer using pumping remediation alone (no abiotic removal or biological degradation effects). Calculations are provided in Appendix D. Therefore, the pump and treat technology in this alternative serves more for hydraulic containment of the contamination plume at AOC 43J than for reduction of contaminant concentrations. Because intrinsic biodegradation is expected to occur in Alternative 4, remediation is expected to be less than the estimated 56 years by hydraulic methods as will be further detailed in the following paragraphs.

As a result of groundwater extraction activity, the average groundwater table level in the plume area is expected to be lowered by as much as 1 foot. Because of partitioning between the soil and groundwater, when the groundwater in the plume area is lowered, residual contamination will be left on the soil above the water table. This residual soil contamination in the vadose zone is addressed by intrinsic bioremediation. If the contamination in the vadose zone soil is not reduced when the groundwater table is lowered, the potential for groundwater recontamination (contamination desorption from the soil) exists when the groundwater table rises again after pump and treat remediation has been halted.

Calculations were performed to estimate the length of time required for intrinsic bioremediation to reduce soil concentrations to levels that would not re-contaminate the groundwater to concentrations exceeding PRGs. These calculations used first order degradation coefficients from the intrinsic solute transport evaluation (Appendix C), average measured soil concentrations, and theoretical soil concentrations that would exist in soil if groundwater CPCs were

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at MCLs. Based on calculation results, it is estimated that it will take approximately 36 years for the contaminants in soils to degrade to concentrations which would not re-contaminate the groundwater above PRGs. Further discussion is provided in Section 4.0. Calculations are provided in Appendix E.

There would be minimal short-term worker exposure to contaminated groundwater during groundwater extraction well and associated piping installation. Further exposure of site workers to site contamination would only exist in the event of groundwater extraction/remediation pipe line failure.

Implementability. Upon completion of field testing and full-scale design, the groundwater pump and treat would be relatively easy to implement. Local contractors and common materials would be available to construct the groundwater extraction and treatment system. Discharge to the Fort Devens WWTF would have to meet the WWTF Industrial Pretreatment Standards (Rasco, 1995). These standards apply to all existing or potential industrial operations (including groundwater remediation systems) discharging to the Fort Devens WWTF. The standards prohibit discharge of any toxic pollutant which may interfere with the Fort Devens WWTF process and which may then pass through the WWTF thereby constituting a hazard, pollute receiving waters, or restrict sludge disposal options selected by Fort Devens. The Commonwealth of Massachusetts Class I groundwater quality parameters are referenced in the Pretreatment Standards. Details regarding compliance requirements are covered in Section 4.0. Implementability for intrinsic bioremediation is discussed under Alternative 2.

Cost. The cost of implementing Alternative 4 would consist primarily of costs for installation of new monitoring wells, groundwater extraction well and treatment system installation, system operation and maintenance and WWTF user fee.

Conclusion. This alternative will be retained for detailed analysis because it will prevent off-site migration and treat contaminants on site.

3.2.4 Alternative 5: Groundwater Collection and Treatment/Soil Treatment

This alternative includes pump and treat for groundwater remediation/hydraulic containment and soil venting for vadose zone remediation. Groundwater extraction and treatment would consist of pumping groundwater from vertical

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groundwater extraction wells and ex-situ treatment of groundwater. This pump and treat remedy would promote active removal of organic contamination and halt groundwater contamination migration.

Soil venting is a vadose zone remediation technology in which VOC-contaminated soil gas would be withdrawn from the vadose zone through a series of vertical vent wells. The principle behind soil venting is to move air through the zone of contamination to promote the volatilization of organic compounds. Air withdrawn from the soil through soil venting would require treatment through vapor phase carbon before discharge to the atmosphere.

Effectiveness. Groundwater pump and treat would reduce the mobility and volume of contamination in site groundwater in two ways. First, because of groundwater extraction activity, groundwater pump and treat would effectively halt the migration of contaminated groundwater. Second, groundwater extraction would reduce the overall mass of contamination in the groundwater by removing groundwater containing dissolved contamination.

Soil venting is a physical transfer process in which VOCs are removed from the vadose zone soil and brought aboveground where they can be treated. Contaminants would be transferred to activated carbon which would require disposal or regeneration. Soil venting effectively reduces the mass of organic contaminants in the vadose zone. As a result, implementation of soil venting would also minimize continual re-exposure of groundwater to contaminants.

Because the extraction of soil gas resulting from the soil venting process also would move oxygen through the vadose zone soil, SVE in the area of AOC 43J would likely promote biological degradation of petroleum hydrocarbons, further reducing the mass of the CPCs.

Based upon modeling information and soil and contaminant characteristics, it is estimated that approximately 56 years would be required to remove all the contamination in the aquifer using pumping remediation alone (no abiotic removal or biological degradation effects). Because it is estimated that biological degradation would continue to occur within the aquifer during groundwater pumping, a maximum estimated time for remediation of the aquifer using hydraulic pumping will be assumed to be the same as that of intrinsic bioremediation (27 years) as described under Alternative 2.

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The potential for short-term worker exposure to contaminated soil may exist for groundwater and vent well installation. Further exposure of site workers to site contamination would only exist in the event of groundwater extraction/remediation or vapor extraction conveyance line failure.

Implementability. Prior to full-scale implementation of soil venting, additional on-site field testing would be required. Field tests would be required to determine the applicability of soil venting to the site soils (soil permeability) and would provide venting system design information such as well layout and operational flow. Upon completion of field testing and full-scale design, both the groundwater pump and treat and soil venting systems would be relatively easy to implement. Local contractors and 'off-the-shelf' materials would be available to construct both the groundwater extraction and treatment, and soil venting systems.

Cost. The cost of implementing Alternative 5 would consist primarily of design testing, groundwater and vent well installation, groundwater treatment system construction, and system operation and maintenance.

Conclusion. This alternative will be retained for detailed analysis because it potentially provides a means of remediating the vadose zone at the site thus minimizing the possibility of re-contaminating the groundwater following groundwater treatment.

TABLE 3-1
ALTERNATIVE 2: INTRINSIC BIOREMEDIATION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

Alternative 2 includes using intrinsic bioremediation for treatment of groundwater and long-term groundwater monitoring (on and off Army Reserve Enclave property) to minimize potential risk to receptors downgradient of the Enclave.

EFFECTIVENESS	IMPLEMENTABILITY	COST
<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> • Intrinsic bioremediation will reduce toxicity/volume of contaminants and also reduce the potential migration of contaminants off the Enclave. • Little or no exposure to site workers during remediation. • Groundwater treatment is achieved with minimal action. <p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> • Reduction in groundwater contamination may take up to 27 years to reach PRGs on-site. • Monitoring of the groundwater plume is required to observe for migration of contaminants off the Enclave. 	<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> • Groundwater monitoring, and and intrinsic bioremediation are readily implementable technologies. • Can use existing groundwater monitoring system supplemented with some additional wells. <p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> • Regulatory approval of intrinsic bioremediation may be more difficult to obtain than for other more conventional processes. • Predesign data collection and modeling required to refine degradation rates and the long-term monitoring plan. 	<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> • Minimal costs associated with intrinsic bioremediation. <p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> • Long-term monitoring costs.

ESTIMATED CAPITAL COST: \$47,200

ESTIMATED PRESENT WORTH OF O&M COSTS: \$394,500

ESTIMATED TOTAL PRESENT WORTH: \$441,700

CONCLUSION: Alternative will be **retained** for detailed analysis. Intrinsic bioremediation, combined with long-term groundwater monitoring provides a low-cost approach that is protective of human health.

Notes:

O&M = operations and maintenance

TABLE 3-2
 ALTERNATIVE 3: INTRINSIC BIOREMEDIATION/ PASSIVE IN-SITU BIOREMEDIATION
 CONTAINMENT
 AOC 43J

FEASIBILITY STUDY REPORT
 FORT DEVENS, MA

Alternative 3 includes using intrinsic bioremediation for treatment of groundwater and implementing passive slow release peroxide for plume containment and groundwater monitoring (on- and off-site) to monitor any threat to receptors downgradient of the Enclave.

EFFECTIVENESS	IMPLEMENTABILITY	COST
<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> Intrinsic bioremediation will reduce toxicity/volume of contaminants. Passive bioremediation will reduce the potential of migration of contaminants off the Enclave. Groundwater treatment and containment is achieved with minimal action. <p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> Reduction in groundwater contamination may take up to 27 years to reach PRGs on-site. Monitoring of the groundwater plume is required to observe for migration of contaminants off the Enclave. 	<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> Groundwater monitoring, passive bioremediation and intrinsic bioremediation are readily implementable technologies. Can use existing groundwater monitoring system supplemented with some additional wells. <p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> Regulatory approval of intrinsic bioremediation may be more difficult to obtain than for other more conventional processes. Predesign data collection and modeling required to refine degradation rates and long-term groundwater monitoring plan. Lab treatability tests/pilot test required to obtain ORC design parameters. 	<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> Slightly lower costs associated with intrinsic bioremediation and passive bioremediation than conventional pump and treat. <p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> Long-term monitoring costs.

ESTIMATED CAPITAL COST: \$134,600

ESTIMATED PRESENT WORTH OF O&M COSTS: \$1,003,400

ESTIMATED TOTAL PRESENT WORTH: \$1,138,000

CONCLUSION: Alternative will be **retained** for detailed analysis. Intrinsic bioremediation, and passive aerobic biological degradation provide a low-cost approach that is protective of human health.

Notes:

O&M = operations and maintenance
 ORC = oxygen release compounds

TABLE 3-3
ALTERNATIVE 4: INTRINSIC BIOREMEDIATION/ HYDRAULIC CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

Alternative 4 includes using intrinsic bioremediation for treatment of groundwater and installing a pump and treat system for hydraulic containment of the plume. Groundwater monitoring (on- and off-site) would be used to monitor for any threat to receptors downgradient of the Enclave.

EFFECTIVENESS	IMPLEMENTABILITY	COST
<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> Intrinsic bioremediation will reduce toxicity/volume of contaminants. The pump and treat system will stop the potential of migration of contaminants off the Enclave. 	<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> Groundwater monitoring, and intrinsic bioremediation are readily implementable technologies. Can use existing groundwater monitoring system supplemented with some additional monitoring wells. 	<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> None.
<p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> Reduction in groundwater contamination may take 36 years to reach PRGs on-site. Soils could recontaminate groundwater when water table rebounds after pumps are shut off. Tight soils restrict flow such that biodegradation to PRGs is expected to occur before pump and treat can reduce contaminants to PRGs. 	<p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> Must meet pretreatment requirements for discharge to the Fort Devens WWTP. Regulatory approval of intrinsic bioremediation may be more difficult to obtain than for other more conventional processes. Need on-site construction for groundwater technology. 	<p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> Long-term monitoring costs and groundwater treatment capital and O&M costs.

ESTIMATED CAPITAL COST \$270,100
ESTIMATED PRESENT WORTH OF O&M COSTS \$1,433,700
ESTIMATED TOTAL PRESENT WORTH \$1,703,800

CONCLUSION: Alternative will be **retained** for detailed analysis. Intrinsic bioremediation, combined with hydraulic containment provides an effective approach that is protective of human health.

Notes: O&M = operations and maintenance

TABLE 3-4
ALTERNATIVE 5: GROUNDWATER COLLECTION AND TREATMENT / SOIL TREATMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

Alternative 5 consists of extracting groundwater for groundwater treatment and hydraulic containment to prevent contaminants from migrating off-site. Intrinsic bioremediation is also used to degrade contaminants below PRGs. Soil venting is used to treat soil above the depressed groundwater table. Groundwater monitoring (on- and off-site) would be used to monitor for any threat to receptors downgradient of the Enclave.

EFFECTIVENESS	IMPLEMENTABILITY	COST
<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> Groundwater treatment, intrinsic bioremediation and SVE will reduce toxicity / volume of contaminants. Pump and treat system will stop the potential migration. SVE treatment will minimize the probability of groundwater becoming recontaminated when the aquifer rebounds to static conditions upon groundwater pump shut-down. 	<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> Groundwater monitoring, and soil vapor extraction are readily implementable technologies. Can use existing groundwater monitoring system supplemented with some additional monitoring wells. 	<p style="text-align: center;"><u>Advantages</u></p> <ul style="list-style-type: none"> None.
<p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> Reduction in groundwater contamination may take 27 years to reach PRGs on-site. SVE test required to assess design parameters. Pumping tests and modeling required to design extraction system. Tight soils restrict flow such that biodegradation to PRGs is expected to occur before pump and treat can reduce contaminants to PRGs. 	<p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> Need on-site construction for groundwater technology. Must meet pretreatment requirements for discharge to the Fort Devens WWTP. 	<p style="text-align: center;"><u>Disadvantages</u></p> <ul style="list-style-type: none"> Long-term monitoring costs and groundwater treatment capital and O&M costs.

ESTIMATED CAPITAL COST: \$388,000

ESTIMATED PRESENT WORTH OF O&M COSTS: \$1,489,900

ESTIMATED TOTAL PRESENT WORTH: \$1,877,900

CONCLUSION: Alternative will be **retained** for detailed analysis. Groundwater treatment, combined with intrinsic bioremediation and soil vapor extraction provides an effective approach that will be protective of human health.

Notes: O&M = operations and maintenance

TABLE 3-5
SCREENING SUMMARY OF ALTERNATIVES
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

REMEDIAL ALTERNATIVES	RETAINED	ELIMINATED
Alternative 1: No Action	X	
Alternative 2: Intrinsic Bioremediation	X	
Alternative 3: Intrinsic Bioremediation/Passive In-situ Bioremedial Containment	X	
Alternative 4: Intrinsic Bioremediation/Hydraulic Containment	X	
Alternative 5: Groundwater Extraction and Treatment / Soil Treatment	X	

4.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

The detailed analysis of alternatives provides a detailed description of each of the AOC 43J remedial alternatives and evaluates them using the evaluation criteria recommended in USEPA RI/FS guidance (USEPA, 1988b). These criteria are described in Table 4-1. The first seven of the evaluation criteria serve as a basis for conducting the detailed analysis, and are addressed in this FS. The remaining two criteria, state and community acceptance, will be addressed after the public comment period on the Proposed Plan. The alternatives that are evaluated in this section are those retained after initial screening in Section 3.0 and listed in Table 3-5. A detailed cost estimate is also included in this detailed analysis for each alternative except the No Action alternative. Costs are broken down by direct and indirect capital costs and O&M costs. The cost estimate includes a present worth analysis to evaluate expenditures that occur over different time periods. This analysis discounts all future costs to a present worth and allows the cost of remedial alternatives to be compared on an equal basis. Present worth represents the amount of money that, if invested now and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life (USEPA, 1988b). A discount rate of 7 percent before taxes and after inflation was used as recommended in OWSER Directive 9355.3-20.

Five alternatives are evaluated in the detailed analysis:

- Alternative 1: No Action
- Alternative 2: Intrinsic Bioremediation
- Alternative 3: Intrinsic Bioremediation / Passive In-Situ Bioremedial Containment
- Alternative 4: Intrinsic Bioremediation / Hydraulic Containment
- Alternative 5: Groundwater Collection and Treatment / Soil Treatment

The No Action alternative was retained as a baseline with which to compare other alternatives. Alternatives 2, 3, 4 and 5 were retained because they provide a

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range in remedial aggressiveness towards meeting the remedial objectives. Alternative 2 provides the simplest approach by permitting natural biological degradation to mitigate contaminants on site and to prevent contaminants that exceed PRGs from migrating across the Army Reserve Enclave boundary. Alternatives 3 and 4 were retained because they provide additional approaches for minimizing the possibility of the CPCs migrating off Army Reserve property. Alternative 5 provides the most aggressive approach to mitigating the site by adding a soil treatment component to hasten remediation of the currently saturated soil zone that contains contaminants which are in equilibrium with the groundwater.

4.1 ALTERNATIVE 1: NO ACTION

This subsection describes the No Action alternative and evaluates the alternative using the seven evaluation criteria except that no cost estimate is provided.

4.1.1 Description

The No Action alternative serves as a baseline alternative with which to compare other remedial alternatives for AOC 43J. The No Action alternative does not contain any additional remedial action components to reduce or control potential risks. Existing activities to maintain existing systems and monitor for potential contaminant migration would be discontinued.

4.1.2 Remedial Alternative Evaluation

The assessment of this alternative using the seven evaluation criteria is presented in the following subsections.

4.1.2.1 Overall Protection of Human Health and the Environment. The No Action alternative has potential for achieving an acceptable level of risk for human receptors. There is no commercial/industrial exposure to contaminated groundwater under current conditions as assessed in the baseline risk assessment. Consequently, there are no current human health risks above USEPA criteria. Furthermore, the site is to remain within the Army Reserve Enclave and will continue to be used to support the reserve training activities (Figure 4-1). Because there will be no future installation of drinking water wells for

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commercial/industrial use on Army Reserve Enclave property, the potential for commercial/industrial exposure to CPCs presenting risks above USEPA criteria is minimal. As discussed in Section 2.0, anaerobic biodegradation of the petroleum hydrocarbons is occurring on site. Groundwater sampling has also shown that contaminants have not migrated past the Army Reserve Enclave boundary to create an unacceptable risk to downgradient receptors. However, without groundwater monitoring activities, there will be no way to assess the effectiveness of biodegradation or the potential for contaminant migration off Army Reserve Enclave property.

4.1.2.2 Compliance with ARARs. Section 4.0 of the Final RI Report provides a preliminary list of potential ARARs for AOC 43J (ABB-ES, 1996). Table 4-2 of this FS Report provides a summary of the ARARs analysis specific for Alternative 1. This alternative has potential for complying with chemical-specific ARARs through naturally occurring biodegradation of the petroleum contamination. However, no monitoring activities will occur with the No Action alternative to evaluate compliance with these ARARs. Federal and Massachusetts drinking water standards are currently met for all CPCs except arsenic, benzene, carbon tetrachloride, ethylbenzene, and toluene in source area groundwater. No ARARs are exceeded in downgradient monitoring wells under average concentration conditions. Only the MCL and Massachusetts Maximum Contaminant Level (MMCL) for benzene is exceeded in downgradient area groundwater under maximum concentration conditions.

Iron (at 10,500 $\mu\text{g/L}$ average and 30,000 $\mu\text{g/L}$ maximum filtered concentrations), exceeds the federal and state aesthetically-based secondary drinking water standards (SMCL and SMMCL) and the Massachusetts Groundwater Quality criterion of 300 $\mu\text{g/L}$. Of these standards, only the Massachusetts Groundwater Quality criterion is considered an ARAR. The Ground Water Quality Standard (314 CMR 6.00) establishes the analyte concentrations and water quality parameters for which groundwater discharge permits are based. Although discharge to site groundwater is not occurring, aquifer quality must be maintained to sustain designated Class 1 use. This alternative will meet the ARAR despite the numerical standard (300 $\mu\text{g/L}$) exceedance because 310 CMR 6.07 states that natural background conditions must be considered in establishing effluent limitations. Fort Devens background iron concentration (9,100 $\mu\text{g/L}$) also exceeds the numerical standard. This alternative will revert the soluble forms of iron back to more insoluble forms upon reduction of the organic contaminants thereby

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reflecting natural background conditions and meeting the Fort Devens background iron concentration.

Similarly, manganese (at 9,600 $\mu\text{g/L}$ average and 18,400 $\mu\text{g/L}$ maximum filtered concentrations) also exceeds the secondary federal and state drinking water standards (SMCL and SMMCL) and the Massachusetts Groundwater Quality criterion of 50 $\mu\text{g/L}$. However, the Fort Devens manganese background concentration of 291 $\mu\text{g/L}$ also exceeds these criteria. The Fort Devens background concentration for manganese will be achieved by this alternative to meet ARARs.

The No Action alternative does not trigger any location-specific or action-specific ARARs.

4.1.2.3 Long-Term Effectiveness and Permanence. The No Action alternative does not provide means to monitor for contaminant reduction or to monitor for migration of contaminants toward the Army Reserve Enclave boundary. It also does not provide a means to verify biodegradation rates to refine the estimated time for restoration completion. However, it does potentially control future commercial/industrial exposure to groundwater at or downgradient of the Army Reserve Enclave property by permanently degrading/destroying the organic CPCs. The Army is retaining ownership of the property and does not propose to install drinking water wells on site. Furthermore, intrinsic bioremediation reduces contaminant concentrations and minimizes the potential for contaminants that exceed PRGs from migrating off Army Reserve Enclave property.

4.1.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment. The No Action alternative utilizes the intrinsic biodegradation process to reduce the toxicity, mobility and volume of contamination. Benzene, carbon tetrachloride, ethylbenzene, and toluene are destroyed in the degradation process. Destruction of these organic compounds will return the groundwater quality (i.e., oxygen content, ORP, and pH) to upgradient conditions resulting in a return of the more insoluble fractions of arsenic, iron and manganese. The No Action alternative does not provide a method of monitoring for reduction of concentration or for verifying that contaminants are not migrating downgradient.

4.1.2.5 Short-Term Effectiveness. This alternative does not provide any active remedial actions at the site that would cause short-term risks to the community or environment as a result of implementation.

4.1.2.6 Implementability. The No Action alternative would be easy to implement and would not interfere with possible future remedial actions. Intrinsic bioremediation is believed to be currently occurring on site.

4.1.2.7 Cost. The No Action alternative does not require any capital or O&M expenditures.

4.2 ALTERNATIVE 2: INTRINSIC BIOREMEDIATION

This subsection describes Alternative 2 and evaluates the alternative using the seven evaluation criteria.

4.2.1 Description

Intrinsic bioremediation is the principal component in Alternative 2 that is proposed to reduce contaminants on Army Reserve Enclave property to below PRGs and also to prevent potential migration of contaminants above PRGs off Army Reserve Enclave property. The installation of additional monitoring wells and implementation of a long-term groundwater monitoring program will enable assessment of the biodegradation progress and permit detection of any potential migration of contaminants beyond the Army Reserve Enclave boundary. Key components of this alternative include:

- intrinsic bioremediation
- predesign data collection and groundwater modeling
- installing additional groundwater monitoring wells
- long-term groundwater monitoring
- five-year site reviews

Each of these components is described in the following paragraphs.

Intrinsic Bioremediation. A discussion of the intrinsic bioremediation process is covered in Subsection 3.1.2, Alternative 2: Intrinsic Bioremediation. Based upon

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organic and inorganic speciation in the aquifer and other water quality parameters, it appears that degradation of the organic CPCs is occurring naturally at AOC 43J. Solute transport calculations were conducted for the site to provide further basis for evaluating intrinsic bioremediation (Appendix C).

An ONED3 analytical model for solute transport from the International Groundwater Modeling Center Solute Program Package (Beljin, 1990) was used for the evaluation. The objective of this evaluation was to simulate existing and future concentrations of benzene, toluene, ethylbenzene and carbon tetrachloride. A groundwater velocity of 0.01 meters per day (m/day) was used in the calculations. This velocity is higher than that calculated using the geometric mean of hydraulic conductivity values from all monitoring wells and piezometers. Therefore, the velocity is conservatively high with regard to contaminant dispersion/transport. Groundwater flow and regional gradient used in the calculations were an approximation of two sets of water level data from the site measured in January 1995 and in May 1995 (Figures 1-8 and 1-9). Degradation rates (half-lives) for the CPCs were obtained from a literature search and are compiled in Appendix C. The decay rates used in the evaluation were typically conservative in allowing for less decay than the average values obtained from the literature. (Half-lives used in the calculations for benzene, toluene, ethylbenzene and carbon tetrachloride were 460 days, 550 days, 1,850 days, and 365 days, respectively.) In all calculation scenarios, the source (assumed to be located between the former gasoline and waste oil USTs) was "turned on" from the years 1960 to 1992 to simulate the leaking USTs which were removed in 1992. Decay rates and source concentration were varied until calculated concentrations were equal to or greater than observed concentrations for the year 1995. Details of the evaluation assumptions are discussed in Appendix C.

The transport calculations predict that none of the organic CPCs will reach the Army Reserve Enclave boundary at concentrations exceeding PRGs. Contaminant concentrations may be reduced below PRGs on site within 5 years for toluene, within 5 to 10 years for benzene and carbon tetrachloride, and within approximately 25 to 30 years for ethylbenzene.

Although not yet statistically significant, it is interesting to note that average concentrations of benzene, toluene, and ethylbenzene decreased 28%, 56%, and 30% between Rounds Five and Six (2.5 months). Carbon tetrachloride could not be readily compared because concentrations were likely below detection limits in

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Round Five. Installation of additional monitoring wells and implementation of a long-term groundwater monitoring program is required to assess the progress of intrinsic bioremediation.

Predesign Data Collection and Groundwater Modeling. Prior to installation of additional groundwater monitoring wells and refinement of a long-term groundwater monitoring plan, additional data collection and modeling is required. Predesign/design work plans would be prepared detailing the proposed activities and submitted to the environmental regulators for review prior to implementation. For cost estimating purposes for this FS, data collection would likely consist of an additional round of groundwater sampling and analysis to refine estimates of intrinsic bioremediation effectiveness in protecting downgradient receptors. Collected data would include groundwater elevation, intrinsic bioremediation indicators, and concentrations for CPCs. Groundwater elevation data would supplement the existing Fort Devens water level data base for this site and would be used to refine groundwater flow direction which appears to vary seasonally. Intrinsic bioremediation indicator data (e.g., electron acceptor concentrations, nutrient concentrations, and oxidation-reduction potential) will be used to provide additional evidence that intrinsic bioremediation is occurring and determine future intrinsic bioremediation potential. CPC concentration data will assist directly in estimating site-specific degradation rates and the effectiveness of intrinsic bioremediation in achieving PRGs.

Data collected from the predesign groundwater sampling will be incorporated into fate and transport modeling. This modeling will assess the degradation and migration of the organic CPCs and refine current estimates of intrinsic bioremediation effectiveness. Initial intrinsic bioremediation modeling will be conducted as part of the alternative predesign phase. The existing and the new groundwater information will be examined to determine the best location for additional groundwater monitoring wells and to finalize site-specific indicator data as required for the design. As additional monitoring data are collected during long-term monitoring (see Long-Term Groundwater Monitoring in this subsection), the fate and transport modeling will be updated to allow the most accurate depiction of current and future groundwater conditions. The fate and transport model used for monitoring intrinsic bioremediation (such as Bioplume II) will be selected based upon the type of groundwater monitoring information gathered and market availability. Details of the model will be proposed as part of the predesign/design work plan.

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Groundwater Monitoring Well Installation. Additional groundwater monitoring wells will be required to improve data collection coverage within and downgradient of the site. The ultimate number and location of additional groundwater monitoring wells for monitoring intrinsic bioremediation at the site will depend upon predesign data results. However, for cost estimation purposes, it is assumed that seven additional monitoring wells would be installed for long-term monitoring of the overburden and bedrock groundwater. These wells would be used to monitor contaminant plume location and concentration in relation to the Army Reserve Enclave boundary and to collect intrinsic biodegradation indicators. A preliminary estimate of monitoring well locations is presented on Figure 4-1. Seven 4-inch diameter PVC monitoring wells approximately 20-feet deep are proposed. Final monitoring well locations and details will be submitted for regulatory review and concurrence in the predesign/design work plan.

Long-term Groundwater Monitoring. Long-term groundwater monitoring is proposed to enable assessment of the intrinsic bioremediation progress and permit detection of any potential migration of contaminants that exceed PRGs beyond the Army Reserve Enclave boundary. Analytical parameters likely to be included in the monitoring program are presented in Table 4-3. Dependent upon the results of the predesign fate and transport modeling, groundwater monitoring would be conducted on an annual basis until three consecutive sampling rounds indicate that cleanup objectives have been met. It is estimated to take 27 years to achieve cleanup objectives plus two additional yearly sampling rounds for a total of 29 years of groundwater monitoring. The last 2 years of monitoring (confirmation) would be for only the CPCs. Refer to Subsection 4.2.2.2 for further discussion regarding remedial action objective time frame. Annual reports would be submitted to MADEP and the USEPA which would include a description of site activities and summary of results of the long-term groundwater monitoring program and modeling updates. Assumptions made for this monitoring plan are for cost estimating purposes only. The final detailed long-term monitoring plan would be developed in conjunction with regulatory agency review and comment.

Five-year Site Reviews. Under CERCLA 121c, any remedial action that results in contaminants remaining on-site must be reviewed at least every five years. During five-year reviews, an assessment is made of whether the implemented remedy continues to be protective of human health and the environment or whether the implementation of additional remedial action is appropriate.

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The five-year site review for Alternative 2 will evaluate the alternative's effectiveness at reducing potential future human health risk from exposure to groundwater on site and downgradient considering current and potential future receptors. This evaluation will be based on how successful the alternative is at attaining PRGs at the long-term monitoring wells.

Specific criteria for evaluating the alternative's progress and effectiveness will be established upon completion of the predesign data collection and groundwater modeling to permit refinement of contaminant transport and degradation estimates. However, for FS purposes, a criterion would be to maintain groundwater quality below PRGs at monitoring wells that historically have revealed concentrations below PRGs (XJM-94-10X, XJM-94-08X, XJM-94-07X, and XJM-94-06X.) Meeting this criterion would demonstrate that the contaminants will not migrate downgradient past the Army Reserve Enclave boundary. It should be noted that, based on FS solute transport calculations, it is possible that ethylbenzene will increase in concentrations (but not exceed PRGs) in downgradient monitoring wells (Appendix C). It is also anticipated that the plume will decrease in concentration over time such that the PRG for ethylbenzene will not be exceeded off Army Reserve Enclave property. A second criterion would be established to demonstrate that the contaminants will eventually degrade to concentrations below PRGs. Reductions will be expected in monitoring wells which have historically revealed concentrations exceeding PRGs (2446-02, 2446-03, 2446-04, XJM-94-05X, XJM-93-03X, XJM-94-09X, XJM-93-04X and XJM-93-02X). Probable assessment criteria (depending upon predesign modeling results) are stated below. These criteria would be used to assess the progress of intrinsic bioremediation and to assess if additional remedial action is appropriate.

Contaminant Migration Assessment: For monitoring wells where analyte concentrations have historically attained PRGs, Alternative 2 will be considered effective if concentrations of individual chemicals within individual monitoring wells do not show statistically significant PRG exceedances. Statistical significance will be assessed using regulatory reviewed and approved methods similar to regulations at 40 CFR 264.97, 40 CFR 258.53 and 310 CMR 306.63.

On-site Contaminant Assessment: For monitoring wells where analyte concentrations have historically exceeded PRGs, Alternative 2 will be

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considered effective if contaminants are reduced to meet PRGs commensurate with the estimates projected by the predesign fate and transport model. Based solely on FS solute transport calculations, reductions should approach over 90% within five years for benzene, toluene, and carbon tetrachloride, and approximately 70% within 15 years for ethylbenzene. Compliance with PRGs is estimated to be obtained within 27 years (Appendix C).

A major consideration in assessing the protectiveness of Alternative 2 and whether additional remedial actions may be appropriate will be the basis on which individual PRGs were set. The Army will consider the implementation of additional remedial actions if the above criteria (as refined based on the predesign fate and transport model) are not met for any chemicals for which PRGs are based on MCLs. The Army will not consider additional remedial actions under CERCLA if PRGs are not attained for iron and manganese. These two analytes are not directly attributable to past activities at AOC 43J but may have increased solubility as a result of the biodegradation of the organic compounds (See Subsection 2.2.1). The soluble concentrations of iron and manganese will likely revert to insoluble fractions once organic concentrations have been reduced. Background concentration variability for iron and manganese within groundwater at Fort Devens adds further evaluation uncertainty. These analytes are identified as noncarcinogenic contributors at AOC 43J, and have only SMCLs (aesthetically based drinking water standards). Iron and manganese are naturally occurring, but problematic analytes which need to be pretreated at most drinking water supply wells in the Fort Devens/Town of Ayer area. Analysis for iron and manganese will be performed during long-term groundwater monitoring in Alternative 2.

4.2.2 Remedial Alternative Evaluation

The assessment of this alternative using the seven evaluation criteria is presented in the following subsections.

4.2.2.1 Overall Protection of Human Health and the Environment. Alternative 2 will be protective of human health and the environment under current land use conditions. There is no commercial/industrial or residential exposure to contaminated groundwater under current conditions. Because the site is to remain Army property, there also will be no future exposure (no drinking water

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source) on site. Furthermore, solute transport calculations suggest that the organic contaminants which pose human health risk will be reduced below PRGs on site (Appendix C). Alternative 2 will not control the potential future installation of drinking water wells for commercial/industrial use downgradient of the Army Reserve Enclave boundary. However, solute transport calculations also indicate that the PRGs for the organic contaminants will not be exceeded downgradient of the Army Reserve Enclave boundary. The installation of additional monitoring wells and implementation of a long-term groundwater monitoring program will further reduce the probability that there could be exposure to contaminants that exceed PRGs beyond the Army Reserve Enclave boundary.

No exposure to ecological receptors currently exists.

4.2.2.2 Compliance with ARARs. Table 4-4 provides a summary of the ARARs analysis specific for Alternative 2. This alternative has potential for complying with chemical-specific ARARs through naturally occurring biodegradation of the petroleum contamination. Monitoring activities would occur with Alternative 2 to evaluate compliance with these ARARs. Discussion regarding current exceedances and compliance are discussed in Subsection 4.1.2.2, Compliance with ARARs for Alternative 1.

Alternative 2 does not trigger any location-specific ARARs. Groundwater monitoring would be in general compliance with the Massachusetts Hazardous Waste Management Rules 310 CMR 30.660 - 30.670 (action-specific ARAR). Although this regulation applies to regulated units which treat, store or dispose of hazardous waste, substantive portions relating to development of a groundwater monitoring plan, monitoring well integrity, determination of groundwater flow rate and direction, and other technical criteria are relevant and appropriate.

4.2.2.3 Long-Term Effectiveness and Permanence. In the microbial degradation process of intrinsic bioremediation, the organic CPCs are ultimately converted to inert compounds such as carbon dioxide, methane, and water. Inorganic CPCs are reverted back to more insoluble forms following completion of organic degradation. Because of the degradation/destruction of organic contaminants that occurs in this process, intrinsic bioremediation provides permanent treatment effectiveness without secondary waste disposal. Long-term groundwater

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monitoring will continue until three consecutive sampling rounds report contaminant concentrations below PRGs.

4.2.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment. Because of the degradation/destruction of organic contaminants that occurs in biological degradation (petroleum hydrocarbons serve as microbiological electron donor/carbon source), intrinsic bioremediation will effectively reduce the toxicity and volume of the CPCs in the groundwater at AOC 43J. As a result of the intrinsic bioremediation process, downgradient or off-site migration of site contaminants will be minimized. Based upon solute transport calculations, organic CPC concentrations on site will be reduced below PRGs.

4.2.2.5 Short-Term Effectiveness. Based upon the solute transport calculations, degradation of the organic CPCs to below PRGs could take up to 27 years (Appendix C). However, because intrinsic bioremediation is an in-situ process, there would be minimal risk to the community. Long-term groundwater monitoring would be utilized to evaluate migration potential of contaminants off Army Reserve Enclave property. The potential for short-term worker exposure to contaminated groundwater is considered minimal during monitoring well installation and sampling. Personnel who install the additional monitoring wells and perform groundwater monitoring will be required to follow a site-specific Health and Safety Plan and utilize personnel monitoring and personal protective equipment to prevent potential exposure to hazardous chemicals. No other remedial activities are associated with Alternative 2 that would endanger the community or environment.

4.2.2.6 Implementability. Water quality parameters indicate that biological degradation is already occurring naturally under existing site conditions. Therefore, no additional services or materials are necessary for the intrinsic bioremediation process itself. The installation of additional groundwater monitoring wells are recommended as part of monitoring to provide additional groundwater characteristic information and to assess contaminant migration. Services, materials and contractors are readily available to install new groundwater monitoring wells. Long-term monitoring would be also be easily implemented and would utilize basic groundwater sampling and analytical techniques.

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The alternative is believed to be reliable. However, predesign data collection and modeling are necessary prior to installing additional monitoring wells and implementing the long-term monitoring plan. The effectiveness of the alternative will be monitored easily through groundwater sampling.

Alternative 2 would not limit or interfere with the ability to perform future remedial actions. The evaluation criteria for successful progressiveness of the alternative is such that, if the alternative is judged unsuccessful, additional remedial action could be readily implemented (i.e. the plume will have migrated very little from the current position).

No off-site activities requiring permits would be undertaken as part of Alternative 2. The five-year review process would require coordination among regulatory agencies.

4.2.2.7 Cost. A cost estimate was prepared for Alternative 2 to assist in selecting a remedial alternative.

Direct capital costs for Alternative 2 include the cost to collect the predesign data, perform the modeling, mobilize a drill rig and install new groundwater monitoring wells. Costs for O&M include maintenance of the groundwater monitoring wells, long-term groundwater monitoring, and five-year site reviews. Table 4-8 summarizes the cost estimate for Alternative 2.

Total Direct and Indirect Costs: \$47,200

Present Worth of O&M costs: \$394,500

Total Present Worth: \$441,700 (27 years treatment/29 years monitoring)

4.3 ALTERNATIVE 3: INTRINSIC BIOREMEDIATION / PASSIVE IN-SITU BIOREMEDIATION CONTAINMENT

This subsection describes Alternative 3, evaluates the alternative using the seven evaluation criteria.

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4.3.1 Description

Alternative 3 for AOC 43J is designed to reduce potential future human health risks. In addition to the components of Alternative 2, this alternative provides installation of passive bioremediation wells to reduce potential future risk to downgradient receptors from potentially contaminated groundwater. The following specific actions are included in Alternative 3:

- intrinsic bioremediation (Subsection 4.2.1)
- installing passive bioremediation wells
- passive in-situ bioremediation system maintenance
- predesign data collection and groundwater modeling (Subsection 4.2.1)
- installing additional groundwater monitoring wells (Subsection 4.2.1)
- long-term groundwater monitoring (Subsection 4.2.1)
- five-year site reviews (Subsection 4.2.1)

Most of these components are discussed in detail in Subsection 4.2.1. To avoid redundancy, only the addition of the passive bioremediation wells component is discussed below.

Intrinsic Bioremediation. Intrinsic bioremediation would be the primary component used to achieve risk reduction for Alternative 3. Refer to Subsection 4.2.1 for further details.

Installing Passive Bioremediation Wells. The objective of the passive bioremediation wells is to promote more aggressive aerobic biological treatment of the downgradient plume edge. This component would help minimize the probability of plume migration off the Army Reserve Enclave boundary. As detailed in Subsection 3.1.3, in general, biological degradation of volatile compounds associated with gasoline (BTEX) is achieved more readily under aerobic conditions than under anaerobic conditions. Passive bioremediation will be performed by introducing oxygen and perhaps mineral nutrients to the aquifer to promote biological remediation of organic CPCs under aerobic conditions. The delivery of oxygen at AOC 43J would be accomplished by placing solid, slow-release metal peroxides in a series of passive bioremediation wells (without withdrawing or reinjecting groundwater). Added nutrients (if required) would be slow release formulations of ammonia nitrogen and phosphate phosphorus.

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Possible amendments could include slow-release ammonium chloride, sodium phosphate, potassium phosphate, or tripolyphosphate, depending on design laboratory treatability testing results.

The passive bioremediation wells would be 2-inch diameter PVC, screened throughout the zone of contamination and fitted with an amendment receptacle. As groundwater passes through the passive bioremediation wells, oxygen and mineral nutrients will dissolve in the groundwater, diffuse into the aquifer, and promote biological degradation of contaminants under aerobic conditions. Although the actual location and number of passive bioremediation wells will depend upon predesign data collection and modeling results, it is estimated for FS purposes that twenty 2-inch passive bioremediation wells and 16 piezometers for monitoring purposes would be required. Preliminary passive bioremediation well locations are presented on Figure 4-2. It is estimated that these well locations will provide adequate aerobic conditions in the downgradient portion of the aquifer.

Passive In-situ Bioremediation System Maintenance. Bioremediation well maintenance will be required to ensure that adequate aerobic conditions are maintained in the downgradient portion of the aquifer at AOC 43J. Maintenance will consist of adding solid oxygen releasing compound and nutrients to the passive bioremediation wells on a regular basis (approximately every three months) and possibly conducting occasional well cleaning. Addition of solid oxygen releasing compound and mineral nutrients would consist of removing the down-well amendment addition receptacle (e.g., cage or sack), placing additional solid oxygen releasing compound and nutrient material (e.g., chips or bricks) in the amendment receptacle, and re-inserting the receptacle into the passive bioremediation well. Well cleaning, which may be required if excessive biological growth or inorganic precipitation occurs in the vicinity of the passive bioremediation wells, would consist of administering standard well cleaning techniques (e.g., surging and acid treatment).

Predesign Data Collection and Groundwater Modeling. As previously discussed for Alternative 2, predesign groundwater data and modeling is required prior to installing additional groundwater monitoring wells and refining the long-term groundwater monitoring plan. This would also be required for Alternative 3. The predesign data would also be used for the positioning of the passive bioremediation wells. Data collection would be as described in Subsection 4.2.1

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but would also include design treatability testing to refine oxygen and nutrient release formulations which would be compatible with the water chemistry at AOC 43J. Predesign/design work plans would be prepared detailing the proposed activities and submitted to the environmental regulators for review prior to implementation.

Long-term Groundwater Monitoring. Long-term groundwater monitoring would be performed as detailed in Alternative 2. Select passive bioremediation wells installed as a component of Alternative 3 would also be sampled to monitor for nutrients and oxygen production.

4.3.2 Remedial Alternative Evaluation

The assessment of this alternative using the seven evaluation criteria is presented in the following subsections. Discussion is generally limited to analysis of the passive bioremediation wells component. Alternative 2 discusses the intrinsic bioremediation component in Subsections 4.2.2.1 through 4.2.2.7.

4.3.2.1 Overall Protection of Human Health and the Environment. Alternative 3 will be protective of human health and the environment for the same reasons as Alternative 2 (Subsection 4.2.2.1). Alternative 3 provides a more aggressive approach at minimizing the potential risk to downgradient receptors by promoting aerobic biological treatment at the downgradient plume edge. Carbon tetrachloride is best degraded under anaerobic conditions and therefore its concentrations may be unaffected by passive application of oxygen. Solute transport calculations suggest that carbon tetrachloride may be one of the faster organic CPCs to degrade (within 5 to 10 years for carbon tetrachloride versus 25 to 30 years for ethylbenzene) (Appendix C). It is more likely that carbon tetrachloride, which only contributes up to 9 percent (5×10^{-5}) to the carcinogenic risk will be degraded under anaerobic conditions within the area of the existing plume as depicted by the solute calculations in Appendix C. The installation of additional groundwater monitoring wells and implementation of a long-term groundwater monitoring program will further reduce the probability that there could be exposure beyond the Army Reserve Enclave boundary.

4.3.2.2 Compliance with ARARs. Table 4-5 provides a summary of the ARARs analysis specific for Alternative 3. Compliance with chemical specific and action specific ARARs will be as detailed in Alternative 2 (Subsection 4.2.2.2).

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Introduction of oxygen and nutrients to the groundwater by passive means would be in general compliance with the Underground Injection Control Program at 40 CFR Parts 144 & 146 and the Underground Water Source Protection Standards at 310 CMR 27.00 through engineering controls.

4.3.2.3 Long-Term Effectiveness and Permanence. Long-term effectiveness and permanence of Alternative 3 will be similar to that of Alternative 2. In the anaerobic microbial degradation process, the organic CPCs are ultimately converted to inert compounds such as carbon dioxide, methane, and water. Alternative 3 also promotes an aerobic degradation process at the plume edge where organic CPCs are converted to carbon dioxide and water. As with Alternative 2, inorganic CPCs are expected to revert back to more insoluble forms following completion of organic degradation. Because organic contaminants are degraded/destroyed in this process, passive bioremediation provides permanent treatment effectiveness without secondary waste disposal. Long-term groundwater monitoring will continue until three consecutive sampling rounds report contaminant concentrations below PRGs.

4.3.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment. Alternative 3 will provide a similar level of toxicity and volume reduction as Alternative 2 (Subsection 4.2.2.4). Alternative 3 has additional protection against contaminant migration because of application of aerobic treatment (passive bioremediation wells) at the plume edge. Carbon tetrachloride will not likely be degraded as readily under aerobic conditions. However, as detailed in Subsection 4.3.2.1, based on solute transport calculations, it is likely to degrade within the area of the existing plume (Appendix C). As a result of the intrinsic bioremediation process and passive biological treatment, downgradient or off-site migration of site contaminants will be minimized. Based upon solute transport calculations, concentrations on site are likely to be reduced below PRGs.

4.3.2.5 Short-term Effectiveness. Based upon the solute transport calculations, degradation of the organic CPCs to below PRGs could take up to 27 years for Alternative 3 (Appendix C). This is the same time for Alternative 2 because the passive in-situ biological treatment method is designed for bioremedial containment and only addresses downgradient contamination. The same discussion in Subsection 4.2.2.5 for Alternative 2 applies to Alternative 3. Because there are more wells (passive bioremediation and monitoring wells) to

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install for Alternative 3, there may be a marginally greater short-term worker exposure during installation and maintenance.

4.3.2.6 Implementability. As detailed in Subsection 4.2.2.6, no additional services or materials are necessary for the intrinsic bioremediation process component. However, the installation of passive bioremediation wells and additional groundwater monitoring wells will be required as part of Alternative 3 and to assess contaminant migration. Services, materials and contractors are readily available to install new groundwater monitoring wells. Currently there is only one manufacturer of magnesium peroxide oxygen releasing compound and several manufacturers of calcium peroxide. Long-term monitoring of the passive bioremediation wells would be implemented easily and would utilize basic groundwater sampling and analytical techniques. Maintenance requirements for the passive bioremediation wells will be further assessed upon performing predesign treatability studies. Iron and manganese could present fouling problems, requiring that the wells be frequently cleaned by surging and acid treatment.

The alternative is believed to be reliable. However, predesign data collection and modeling are necessary prior to installing additional monitoring wells and implementing the long-term monitoring plan. The effectiveness of the alternative will be monitored easily through groundwater sampling.

Alternative 3 would not limit or interfere with the ability to perform future remedial actions. The evaluation criteria for successful progressiveness of the alternative is such that, if the alternative is judged unsuccessful, additional remedial action could be readily implemented (i.e., the plume will have migrated very little from the current position).

No off-site activities requiring permits would be undertaken as part of Alternative 3. The five-year review process would require coordination among regulatory agencies.

4.3.2.7 Cost. In addition to cost items listed for Alternative 2 (Subsection 4.2.2.7), Alternative 3 direct capital costs include expenses for predesign treatability testing and installation of 20 passive bioremediation wells and 16 piezometers. Additional O&M costs include purchase of the oxygen releasing compound and nutrients, and maintenance of these wells. Maintenance

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expense assumes five oxygen releasing compound/nutrient exchanges and one surge/acid treatment per year. Table 4-9 summarizes the cost estimate for Alternative 3.

Total Direct and Indirect Costs: \$134,600

Present Worth of O&M costs: \$1,003,400

Total Present Worth: \$1,138,000 (27 years treatment / 29 years monitoring)

4.4 ALTERNATIVE 4: INTRINSIC BIOREMEDIATION / HYDRAULIC CONTAINMENT

This subsection describes Alternative 4 and evaluates the alternative using the seven evaluation criteria.

4.4.1 Description

Alternative 4 for AOC 43J is designed to reduce potential future human health risks by using intrinsic bioremediation to degrade CPCs below PRGs on site and using groundwater extraction and treatment to hydraulically contain and also to treat the contaminant plume. This alternative is similar to Alternative 3 except the plume would be contained hydraulically rather than by aerobic biodegradation to reduce potential future risk to downgradient receptors. Calculations based on site soil and contaminant characteristics reveal that up to 56 years may be required to remove all the contamination in the aquifer using pumping remediation alone (no abiotic removal or biological degradation effects) (Appendix D). Intrinsic bioremediation is expected to reduce CPCs to below PRGs in less time as will be detailed below. Therefore, the groundwater extraction and treatment component in this alternative serves more for hydraulic containment of the contaminant plume while reduction of contaminant concentrations would be shared both by intrinsic bioremediation and groundwater extraction. Extraction wells would be positioned within the higher contaminated portion of the plume to maximize treatment efficiency for this alternative. The following specific actions are included in Alternative 4:

- intrinsic bioremediation (Subsection 4.2.1)
- predesign data collection and design
- groundwater treatment facility construction
- groundwater treatment facility operation and maintenance

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- installing additional groundwater monitoring wells
- long-term groundwater and soil monitoring
- five-year site reviews (Subsection 4.2.1)

Many of these components are discussed in detail in Subsection 4.2.1. To avoid redundancy, only the addition of the groundwater treatment facility extraction, treatment and discharge components is discussed below. Details pertaining to the treatment facility design are conceptual and are presented only for FS cost estimating purposes.

Intrinsic Bioremediation. Intrinsic bioremediation would be one of the components used to achieve risk reduction for Alternative 4 (See Subsection 4.2.1 for further details on intrinsic bioremediation in groundwater). As previously discussed in Subsection 4.2.1, intrinsic biodegradation of CPCs below PRG in the groundwater is estimated to take approximately 27 years. Alternative 4 may take longer than 27 years because of the lowering of the groundwater table from groundwater extraction (as much as 1 foot). Because of partitioning between the soil and groundwater, residual contamination will be left on the soil above the water table when the groundwater in the plume area is lowered. This residual soil contamination in the vadose zone is addressed by intrinsic bioremediation. If the contamination in the vadose zone soil is not reduced when the groundwater table is lowered, the potential for groundwater recontamination (contamination desorption from the soil) exists when the groundwater table rises again after groundwater extraction has been halted.

Calculations were performed to estimate the length of time required to reduce contaminant concentrations (through intrinsic bioremediation) within soil to levels that would not re-contaminate the groundwater above PRGs (Appendix E). Calculations used first order degradation coefficients from the solute transport evaluation, average measured soil concentrations, and theoretical soil concentrations that would exist in soil if groundwater CPCs were at PRGs (Appendix C). Based on calculation results, it is estimated that it will take approximately 36 years for the soil contaminants to degrade to concentrations which will not re-contaminate the groundwater above PRGs.

Pre-design Data Collection and Design. A design would be performed for Alternative 4 which would detail the layout, equipment and materials required for installing the groundwater extraction, treatment, and discharge system. Site-

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specific geologic and hydrogeological data would need to be collected prior to commencing with the design. This data would be used to model more accurately the number and location of extraction wells, and flow rates required to capture the groundwater plume. Emphasis would be placed on modeling the hydrogeologic conditions at the site in Alternative 4, as opposed to intrinsic biodegradation/solute transport modeling as would be performed in Alternatives 2 and 3. Although intrinsic bioremediation is anticipated to minimize the remedial period, risk reduction by groundwater extraction and treatment alone should be achievable (hydraulic containment and extraction). Existing site survey data and utility drawings would also be collected to assist in site layout. Treatability studies are not believed to be warranted as the organic CPCs are readily treatable using activated carbon. As part of the design process, system design criteria would be assembled and would be the basis for appropriate and cost-effective system. The design of the groundwater extraction, treatment and discharge system would be submitted to the environmental regulators for review prior to implementation.

Groundwater Treatment Facility Construction. For FS cost estimating purposes, preliminary modeling was performed to estimate the pumping rate that would be required for this remedial alternative using three groundwater extraction wells to capture the groundwater plume at the site (Appendix B). The estimated total groundwater flow rate from the three extraction wells is 1 gpm. The objective of groundwater extraction is to halt the migration of the contaminant plume. The wells would be located within the higher contaminated portion of the plume to maximize contaminant extraction efficiency and arranged to optimize hydraulic containment. The extraction wells would be constructed of 6-inch diameter, schedule 40, PVC. Grain size of the sandpack material in the annular space around the screen would be compatible with the slot size of the well screen and the surrounding formation. A manhole with cover would be installed over each extraction well riser to allow access to the well and pump.

An conceptual process flow diagram is shown in Figure 4-3. Extracted groundwater would be pumped to the treatment building through buried influent piping. The single-walled influent piping would be connected through the side of the manholes below the frost line. The pumps would be a low flow type such as a pneumatically operated pump using compressed air. The compressed air lines would also be buried in the trench with the influent piping.

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A permanent treatment building would be built in the vicinity of the groundwater extraction wells to minimize the extent of trenching and piping run lengths. The building would be a simple wood frame structure constructed on a concrete foundation and slab. The building would be insulated and heated for year-round use. Electric power would be brought to the building by an overhead service connection. The treatment process would consist of an equalization tank with level controls that activate a discharge pump that forces the collected groundwater through a bag filter and then through two GAC canisters placed in series mode.

The groundwater extraction pumps would be powered from a compressor located inside the building. A control panel for the extraction pumps would be inside the building and would be used to control the flow rate and water level in the extraction wells. A high/low level control switch would operate the discharge pump from the equalization tank. A high/high level switch in the equalization tank would shut down the groundwater extraction pumps to prevent the tank from over-filling. The equalization tank would be approximately 250 gallons in capacity and constructed of polyethylene. The filter bag system would consist of a bag housing for a filter bag, which would remove suspended solids from the groundwater stream prior to being pumped through the carbon canisters. The canisters would contain 200 lbs of GAC each and would be suitable for use in removing VOC contaminants from the groundwater.

Final effluent would meet pretreatment regulations and would be discharged to the Fort Devens WWTF via a nearby sewer manhole. The Fort Devens WWTF is a primary treatment facility (bar screen, two comminutors, Imhoff Tank, 22 rapid infiltration beds, and four sludge drying beds). The facility was initially designed (1941) to receive a flow of three million gallons of wastewater per day (mgd). Recorded flows have gradually decreased from 1.9 in 1986 to 0.5 mgd in 1994.

Groundwater Treatment System Operation and Maintenance. Operation of the treatment system would consist of pumping approximately 1 gpm of groundwater to the equalization tank. The discharge pump for the equalization tank would pump at a rate slightly higher than the anticipated groundwater flow rate and would therefore cycle on and off based on the water elevation in the tank. The bag filter would be replaced on an approximately weekly basis or as needed based on back pressure build-up in the bag filter system. The carbon canisters would be changed as needed based on VOC analytical results from sampling before,

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between, and after the carbon canisters. The carbon would be replaced such that when the primary carbon canister was exhausted it would be removed from the system and shipped off-site for disposal or regeneration. The secondary carbon canister would be piped into the primary position and a new canister would be put into the secondary position. For purposes of estimating carbon consumption, an average VOC concentration was estimated from nearby monitoring wells.

Discharge to the Fort Devens WWTF will meet the WWTF Industrial Pretreatment Standards (Rasco, 1995). The standards prohibit discharge of any toxic pollutant which may interfere with the Fort Devens primary wastewater treatment facility process. The Commonwealth of Massachusetts Class I groundwater quality parameters are referenced in the Pretreatment Standards. Organic CPCs are to be treated to MCLs and will meet discharge requirements. It is assumed for purposes of the treatment system conceptual design that effluent limits for iron and manganese will be equal to their respective background concentrations because background concentrations for these inorganics exceed the Fort Devens WWTF pretreatment limits. In accordance with the Massachusetts Groundwater Quality Standards 310 CMR 6.07 background concentrations must be considered when establishing effluent limits.

Iron and manganese, once brought to the surface and exposed to oxygen within the equalization tank, are expected to become more insoluble and be filtered to concentrations that approximate Fort Devens background concentrations (9,100 $\mu\text{g/L}$ and 291 $\mu\text{g/L}$, respectively). Fort Devens background concentrations for iron and manganese exceed the Commonwealth of Massachusetts secondary effluent limitations for Class 1 groundwater specified in the Pretreatment Standards.

At some locations at the site, arsenic concentrations are slightly above the permitted limit of 50 $\mu\text{g/L}$ for discharge to the Fort Devens WWTF. These exceedances occur upgradient of the proposed extraction wells and range from 53 to 73 $\mu\text{g/L}$. During initial operation of groundwater extraction system, the arsenic concentrations of in the extracted groundwater is anticipated to be close to the current average arsenic concentration for the site (30 $\mu\text{g/L}$) which will meet pretreatment standards. This estimate is based on the observed average concentrations detected in groundwater monitoring wells in Rounds Five and Six. Some arsenic precipitation and removal is also likely to occur on the bag filters and in the carbon canisters, further lowering the discharge concentration of

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arsenic. Also during the course of remediation the arsenic concentration at the site would be expected to drop to background concentrations because of the remediation of the VOC contaminants, which have caused naturally occurring arsenic in the soils to go into solution.

Upon satisfactory treatment system start-up, system discharge would be sampled monthly to ensure compliance with discharge limits.

Groundwater Monitoring Well Installation. Additional groundwater monitoring wells will be required to improve monitoring coverage within and downgradient of the site. The ultimate number and location of additional groundwater monitoring wells for monitoring hydraulic containment and reduction in concentrations of CPCs at the site will depend upon predesign data and modeling results. For cost estimating purposes, it is assumed that seven additional monitoring wells as detailed in Alternative 2 (Subsection 4.2.1 and Figure 4-1) would be installed for long-term groundwater monitoring purposes. Final well locations and details will be submitted for regulatory review and concurrence.

Long-term Groundwater and Soil Monitoring. Long-term groundwater and soil monitoring is proposed to enable assessment of the site mitigation progress and permit detection of any potential migration of groundwater CPCs that exceed PRGs beyond the Army Reserve Enclave boundary. Analysis would be for organic and filtered inorganic CPCs in groundwater samples and organic CPCs in soil samples. Groundwater monitoring would be conducted on an annual basis until three consecutive sampling rounds indicate that cleanup objectives have been met. It is estimated to take 36 years to achieve cleanup objectives in Alternative 4 plus two additional yearly sampling rounds for a total of 38 years of groundwater monitoring. Soil sampling would be performed every five years to monitor for degradation of contaminants within the groundwater rebound zone. Annual reports would be submitted to MADEP and the USEPA which would include a description of site activities and summary of results of the long-term groundwater and soil monitoring program. Assumptions made for this monitoring plan are for cost estimating purposes only. A final detailed long-term monitoring plan would be developed in conjunction with regulatory agency review and comment.

Five-year Site Reviews. The five-year review paragraph in Subsection 4.2.1 (Alternative 2) also applies to Alternative 4 with the exception of references to

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fate and transport modeling. Alternative 4 modeling will be for hydrogeologic purposes.

4.4.2 Remedial Alternative Evaluation

The assessment of this alternative using the seven evaluation criteria is presented in the following subsections. Discussions in Subsections 4.2.2.1 through 4.2.2.7 (Alternative 2) regarding intrinsic bioremediation also apply to the following evaluations.

4.4.2.1 Overall Protection of Human Health and the Environment. Alternative 4 will be protective of human health and the environment under current land use conditions. There is no commercial/industrial or residential exposure to contaminated groundwater under current conditions. Because the site is to remain Army property, there also will be no future exposure (no drinking water source) on site. Furthermore, solute transport calculations suggest that the organic contaminants which pose human health risk will be reduced below PRGs on site through intrinsic bioremediation (Appendix C). Groundwater extraction and treatment also will be removing these contaminants as biodegradation progresses. Groundwater extraction provides hydraulic containment of the CPCs to minimize potential exposure to possible future receptors downgradient of the Army Reserve Enclave boundary. The installation of additional monitoring wells and implementation of a long-term groundwater and soil monitoring program will further reduce the probability that there could be exposure to contaminants that exceed PRGs beyond the Army Reserve Enclave boundary.

No exposure to ecological receptors currently exists.

4.4.2.2 Compliance with ARARs. Table 4-6 provides a summary of the ARARs analysis specific for Alternative 4. This alternative has potential for complying with chemical-specific ARARs through naturally occurring biodegradation of the petroleum contamination and through groundwater extraction and treatment. Monitoring activities would occur with Alternative 4 to evaluate compliance with these ARARs. Discussion regarding current exceedances and compliance are discussed in Subsection 4.1.2.2, Compliance with ARARs for Alternative 1.

Alternative 4 does not trigger any location-specific ARARs. Action-specific ARARs discussed in Alternative 2 (Subsection 4.2.2.2) also apply to Alternative 4.

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Additionally, the discharge of non-domestic wastewater to a WWTF must comply with the Clean Water Act, General Pretreatment Program (40 CFR Part 403). Treatment wastes (i.e., activated carbon, filtered material, and sludge) would be tested to evaluate if they are classified as a characteristic hazardous waste in accordance with Resource Conservation and Recovery Act (RCRA) Land Disposal Restrictions (40 CFR 268). Engineering controls (dust suppression) would be used to comply with Massachusetts Air Pollution Control Regulations (310 CMR 6.00 - 7.00) which would regulate particulate emissions during site construction activities.

4.4.2.3 Long-Term Effectiveness and Permanence. Discussions regarding long-term effectiveness in Alternative 2 for intrinsic bioremediation (Subsection 4.2.2.3) also apply to Alternative 4. The groundwater extraction and treatment process also permanently removes the CPCs from the groundwater. However, as previously discussed, the potential for groundwater recontamination exists when the groundwater table rises again after groundwater extraction has been halted (if the contamination in the vadose zone soil is not reduced). Soil sampling would be performed to evaluate the progressiveness of biodegradation in the vadose zone. Long-term groundwater monitoring will continue until three consecutive sampling rounds report contaminant concentrations below PRGs.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment. Discussions regarding reduction of toxicity, mobility, and volume of CPCs in Alternative 2 for intrinsic bioremediation (Subsection 4.4.2.4) also apply to Alternative 4. Groundwater extraction and treatment will reduce the toxicity, mobility and volume of the CPCs at the site by removing these compounds. However, pretreatment wastes (i.e., tank sludge and filters) will require final disposal. Spent activated carbon will also require disposal and is often regenerated by the supplier.

4.4.2.5 Short-Term Effectiveness. Discussions regarding short-term effectiveness in Alternative 2 for intrinsic bioremediation (Subsection 4.2.2.5) also apply to Alternative 4. As previously detailed in Subsection 4.4.1, calculations reveal that it will take up to 36 years for the soil contaminants to degrade to concentrations which will not re-contaminate the groundwater above PRGs (Appendix E). Because wastes are generated from the groundwater treatment system there would be some added potential exposure (minimal) to the community and environment. Long-term groundwater monitoring would be utilized to evaluate migration

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potential of contaminants off Army Reserve Enclave property. The potential for short-term worker exposure to contaminated groundwater is increased because of ex-situ treatment processes during equipment maintenance (tank cleaning, filter changes, carbon replacement) but is considered minimal for monitoring well installation and sampling. Personnel who operate the treatment facility, install the additional monitoring wells, and perform groundwater monitoring will be required to follow a site-specific Health and Safety Plan and utilize personnel monitoring and personal protective equipment to prevent potential exposure to hazardous chemicals. No other remedial activities are associated with Alternative 4 that would endanger the community or environment.

4.4.2.6 Implementability. Discussions regarding implementability in Alternative 2 for intrinsic bioremediation (Subsection 4.2.2.6) also apply to Alternative 4 except that the need for intrinsic biodegradation data collection and modeling would not be required because of the groundwater extraction system installation.

The installation of groundwater extraction wells for the treatment system will require further modeling to refine the number, placement and pumping rates to hydraulically contain the plume. Upon completion of field testing and full-scale design, the treatment system would be easy to operate but would require regular maintenance and monitoring. Discharge to the Fort Devens WWTF would require monitoring for compliance with existing pretreatment standards (Rasco, 1995). Services, materials and contractors are readily available to construct a groundwater extraction, treatment and discharge system of this size. Long-term monitoring would be also be easily implemented and would utilize basic groundwater/soil sampling and analytical techniques.

The alternative is believed to be reliable. However, predesign data collection and modeling are necessary to properly locate the extraction wells and implement the long-term monitoring plan. The effectiveness of the alternative will be monitored easily through groundwater sampling. The possibility of the soil re-contaminating the groundwater upon aquifer rebound may be difficult to assess with soil sampling because of the heterogeneous soil medium.

Alternative 4 would not limit or interfere with the ability to perform future remedial actions. The five-year review process would require coordination among regulatory agencies.

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4.4.2.7 Cost. A cost estimate was prepared for Alternative 4 to assist in selecting a remedial alternative. Remedial action is expected to exceed the 30-year default period specified in USEPA guidance (USEPA, 1988) for cost analyses purposes. However, because the remedial time frames for Alternatives 2, 3, and 4 were evaluated using the same or similar modeling techniques and assumptions, the actual estimated time of 36 years (38 years for groundwater monitoring) will be used so that the costs between alternatives may be evaluated on an equal basis. (i.e., Alternatives 2 and 3 are expected to take up to 27 years for site mitigation. Comparing costs incurred for this period with costs incurred for a default period of 30 years for Alternative 4 would appear to be a biased analysis.)

Direct capital costs for Alternative 4 include the costs to collect the predesign data, perform hydrogeologic modeling, and to design and construct the groundwater extraction/treatment system described above. Components include the building, equipment, extraction wells, trenching, and connection to the sanitary sewer. Also included are expenses for mobilizing a drill rig to install new groundwater monitoring wells.

O&M costs for the groundwater extraction and treatment facility include weekly site visits by a technician, carbon use of four to five change-outs per year (based on a VOC concentration equivalent to 2.9 mg/L of benzene), disposal of the bag filters as a special waste, monthly VOC sampling and analysis, reporting, and WWTF user fee. Other O&M costs include long-term groundwater monitoring (analysis for CPCs once per year), long-term soil sampling (assumed frequency one sampling round of 10 soil samples each, every five years) and five-year site reviews. Table 4-10 summarizes the cost estimate for Alternative 4.

Total Direct and Indirect Costs: \$270,100

Present Worth of O&M costs: \$1,433,700

Total Present Worth: \$1,703,800

4.5 ALTERNATIVE 5: GROUNDWATER COLLECTION AND TREATMENT / SOIL TREATMENT

This subsection describes Alternative 5 and evaluates the alternative using the seven evaluation criteria.

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4.5.1 Description

Alternative 5 involves installation of a groundwater extraction and treatment system as detailed in Alternative 4. As previously discussed in Alternative 4, residual contamination may be left on the soil above the water table when the groundwater in the plume area is lowered during groundwater extraction.

Alternative 4 includes installation of a soil vapor extraction system to remediate contaminated soils which will be left above the lowered groundwater table. The objectives of groundwater extraction and treatment are a) to halt/minimize the migration of the contamination plume (hydraulic control) and b) to remediate the aquifer. The objective of soil venting is to remediate the vadose zone and to prevent recontamination of the groundwater upon rebounding of the aquifer. The combination of groundwater extraction and treatment, soil vapor extraction, and intrinsic bioremediation will minimize the potential of off-site migration of groundwater CPCs and remediate site soil and groundwater. The following specific actions are included in Alternative 5:

- predesign data collection and design
- SVE treatment system installation
- groundwater treatment facility construction (Subsection 4.4.1)
- installing additional groundwater monitoring wells (Subsection 4.4.1)
- groundwater treatment facility operation and maintenance (Subsection 4.4.1)
- soil monitoring
- long-term groundwater monitoring
- five-year site reviews (Subsection 4.2.1)
- intrinsic bioremediation (Subsection 4.2.1)

Many of these components are discussed in detail in Subsections 4.2.1 and 4.4.1. In general, only the addition of the soil vapor extraction component is discussed below.

Predesign Data Collection and Design. Predesign data collection and design for the groundwater extraction and treatment system for Alternative 5 would be as described in Alternative 4 (Subsection 4.4.1). Predesign data collection needs for the SVE system would include performing a permeability (and respiration) test to assess removal efficiency and to collect full-scale design information. Permeability testing would consist of installing one vent well and approximately five vapor

SECTION 4

monitoring wells in the region of XJM-94-05X, operating a blower for a period of 48 hours, and monitoring the pressure/vacuum response in surrounding vapor monitoring wells. Respiration testing (which would evaluate the role of biological degradation in soil venting), would consist of monitoring oxygen utilization and carbon dioxide production in the vented vadose soil for a period of approximately 72 hours. Based upon information obtained from testing, the design of a full-scale soil venting system could be finalized (e.g. number of vent wells, well locations, and venting flow rates).

SVE Treatment System Installation. A system of vent wells will be used to treat the vadose zone contamination left above the groundwater during groundwater extraction (approximately 11,000 square feet as presented in Figures 2-3 through 2-8). The ultimate number and location of soil vent wells would depend upon pilot test results. For cost estimation purposes, it was assumed that nine 2-inch vent wells would be installed for vadose zone treatment. The preliminary soil venting well locations are presented on Figure 4-4. In addition to soil vent wells, approximately five vapor monitoring wells (from the pilot test) would be used to monitor soil vapor concentrations within the XJM-94-05X area. Specific details regarding soil volumes to be treated, assumed soil permeability, and air flow rates are discussed in Subsection 3.1.5, Alternative 5: Groundwater Collection and Treatment / Soil Treatment.

Soil vapor that is removed from the ground as part of soil venting would require treatment. Although the final soil vapor treatment design would be determined after pilot scale testing, for estimation purposes, it is assumed that vapor phase activated carbon would be used for soil vapor treatment. Soil venting piping, which would connect soil vapor wells to the system blower, would be installed below ground to avoid disturbance of aboveground activities. All the aboveground system components including the blower, controls, and soil vapor treatment equipment, would be housed in the groundwater treatment facility building for weather protection.

Soil Vapor Monitoring. Soil vapor monitoring will serve the two purposes of determining the efficiency of soil venting in cleaning the vadose zone (which prevents further groundwater contamination) and determining the effectiveness of the soil vapor treatment equipment in treating the extracted soil vapors. Data that will be collected as part of vadose zone monitoring include VOC concentrations in the extracted soil vapor stream (treated and untreated) and

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oxygen, carbon dioxide, and VOC concentrations in the soil vapor monitoring wells. VOC measurements would be used to assess the progress of soil venting and the efficiency of the soil gas treatment system.

The VOC concentrations will be measured in the extracted and treated soil vapor streams using a PID once per week and by gas chromatograph (GC) analysis for the organic CPCs once per month. It is anticipated that the soil vapor treatment equipment will be monitored weekly during operation (estimated to be two years to reach targeted soil concentrations).

Monitoring will also involve measuring changes in oxygen and carbon dioxide concentrations in the soil vapor monitoring wells to assess biological degradation as a result of soil venting. In addition, VOC concentrations in the vapor monitoring wells will also be measured to indicate the progress of the venting treatment. Soil vapor monitoring wells would be sampled and analyzed on a semi-annual basis for the duration of the project (estimated to be two years). Confirmation soil samples will be collected from the contaminated area following SVE shutdown (ten off-site laboratory soil samples analyzed for organic CPCs assumed for cost purposes).

Long-term Groundwater. Long-term groundwater monitoring is proposed to enable assessment of the site mitigation progress and permit detection of any potential migration of groundwater CPCs that exceed PRGs beyond the Army Reserve Enclave boundary. Analysis would be for organic and filtered inorganic CPCs. Groundwater monitoring would be conducted on an annual basis until three consecutive sampling rounds indicate that cleanup objectives have been met. As previously discussed in Subsection 4.2.1, intrinsic biodegradation of CPCs below PRG in the groundwater is estimated to take approximately 27 years (plus two additional yearly sampling rounds for a total of 29 years of groundwater monitoring). Annual reports would be submitted to MADEP and the USEPA which would include a description of site activities and summary of results of the long-term groundwater and soil monitoring program. Assumptions made for this monitoring plan are for cost estimating purposes. A final detailed long-term monitoring plan would be developed in conjunction with regulatory agency review and comment.

Five-year Site Reviews. The five-year review paragraph in Subsection 4.2.1 (Alternative 2) also applies to Alternative 5 with the exception of references to

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fate and transport modeling. Alternative 5 modeling will be for hydrogeologic purposes.

4.5.2 Remedial Alternative Evaluation

The assessment of this alternative using the seven evaluation criteria is presented in the following subsections. Discussions in Subsections 4.4.2.1 through 4.4.2.7 (Alternative 4) regarding groundwater extraction and treatment also apply to the following evaluations.

4.5.2.1 Overall Protection of Human Health and the Environment. Alternative 5 will be protective of human health and the environment under current land use conditions. There is no commercial/industrial or residential exposure to contaminated groundwater under current conditions. Because the site is to remain Army property, there also will be no future drinking water source on site. Furthermore, solute transport calculations suggest that the organic contaminants which pose human health risk will be reduced below PRGs on site through intrinsic bioremediation (Appendix C). Groundwater extraction and treatment combined with SVE will also remove these contaminants as biodegradation progresses. Groundwater extraction provides hydraulic containment of the CPCs to minimize potential exposure to possible future receptors downgradient of the Army Reserve Enclave boundary. The installation of additional monitoring wells and implementation of a long-term groundwater will further reduce the probability that there could be exposure to contaminants that exceed PRGs beyond the Army Reserve Enclave boundary.

No exposure to ecological receptors currently exists.

4.5.2.2 Compliance with ARARs. Table 4-7 provides a summary of the ARARs analysis specific for Alternative 5. Compliance with ARARs for Alternative 5 will be as described for Alternative 4 (Subsection 4.4.2.2.). Additionally, the soil venting treatment system will comply with the Massachusetts Air Pollution Control regulations (310 CMR 7.03). These regulations require a minimum 95% reduction (by weight) reduction in VOCs in the air effluent stream.

4.5.2.3 Long-Term Effectiveness and Permanence. Discussions regarding long-term effectiveness in Alternative 2 for intrinsic bioremediation (Subsection 4.2.2.3) and in Alternative 4 for groundwater extraction (Subsection 4.4.2.3) also apply to

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Alternative 5. The SVE process also permanently removes the CPCs from the soil preventing re-contamination of the groundwater. However, as previously discussed, the potential for groundwater recontamination exists when the groundwater table rises again after groundwater extraction has been halted (if the contamination in the vadose zone soil is not reduced). Soil monitoring from soil vapor monitoring wells would be performed to evaluate the progressiveness of SVE/biodegradation in the vadose zone. Long-term groundwater monitoring will continue until three consecutive sampling rounds report contaminant concentrations below PRGs.

4.5.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment.

Discussions regarding reduction of toxicity, mobility and volume of CPCs in Alternative 2 for intrinsic bioremediation (Subsection 4.4.2.4) and in Alternative 4 for groundwater extraction (Subsection 4.4.2.4) also apply to Alternative 5. SVE will reduce the toxicity, mobility and volume of the CPCs at the site by removing these compounds. However, the vapor phase carbon used in treatment of SVE system effluent will require final disposal or regeneration.

4.5.2.5 Short-Term Effectiveness. Discussions regarding short-term effectiveness in Alternative 2 for intrinsic bioremediation (Subsection 4.2.2.5) and in Alternative 4 for groundwater extraction and treatment (Subsection 4.4.2.5) also apply to Alternative 5. As discussed in Subsection 4.4.1, calculations indicate that it will take up to 27 years for the CPCs in groundwater to degrade to below PRGs (Appendix C). SVE treatment is expected to take 2 years to reduce soil contaminants to target concentrations such that they will not re-contaminate the rebounding water. Therefore, Alternative 5 will mitigate the site within 27 years. Because wastes are generated from the groundwater treatment system and SVE system there would be some added potential exposure (minimal) to the community and environment. Long-term groundwater monitoring would be utilized to evaluate migration potential of contaminants off Army Reserve Enclave property. The potential for short-term worker exposure to contaminated groundwater is increased because of groundwater extraction/treatment and SVE processes during equipment maintenance (i.e., tank cleaning, filter changes, and carbon replacement) but is considered minimal for monitoring well installation and sampling. Personnel who operate the treatment facilities, install the additional groundwater monitoring wells, and perform groundwater monitoring will be required to follow a site-specific Health and Safety Plan and utilize personnel monitoring and personal protective equipment to prevent potential

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exposure to hazardous chemicals. No other remedial activities are associated with Alternative 5 that would endanger the community or environment.

4.5.2.6 Implementability. Discussions regarding implementability in Alternative 2 for intrinsic bioremediation (Subsection 4.2.2.6) also apply to Alternative 5 except that the need for intrinsic bioremediation data collection and modeling would not be required because of the groundwater extraction system installation.

Implementability discussions for Alternative 4 groundwater extraction and treatment (Subsection 4.4.2.6) also apply to Alternative 5. The installation of the SVE system will require pilot testing to refine the number, placement and flow rates to effectively remove the organic CPCs from the vadose zone. Upon completion of field testing and full-scale design, the SVE system could be operated with minimal effort but would require regular maintenance and monitoring. Services, materials and contractors are readily available to construct an SVE system of this size. Long-term groundwater monitoring would be also be easily implemented and would utilize basic groundwater sampling and analytical techniques.

The alternative is believed to be reliable. However, a pilot test is necessary to properly design the SVE system. Additionally, the possibility of groundwater recontamination upon aquifer rebound may be difficult to assess with soil monitoring and sampling because of the heterogenous soil medium and short circuiting.

Alternative 5 would not limit or interfere with the ability to perform future remedial actions. The five-year review process would require coordination among regulatory agencies.

4.5.2.7 Cost. A cost estimate was prepared for Alternative 5 to assist in selecting a remedial alternative.

Direct capital costs for Alternative 5 include all the costs discussed for Alternative 4 (Subsection 4.4.2.7) plus expenses incurred for pilot testing, design, and construction of the SVE system.

O&M costs for the SVE system include weekly site visits by a technician, carbon use and disposal, monthly GC analysis of the air streams, semi-annual measurements from the soil vapor monitoring wells and reporting over a two year

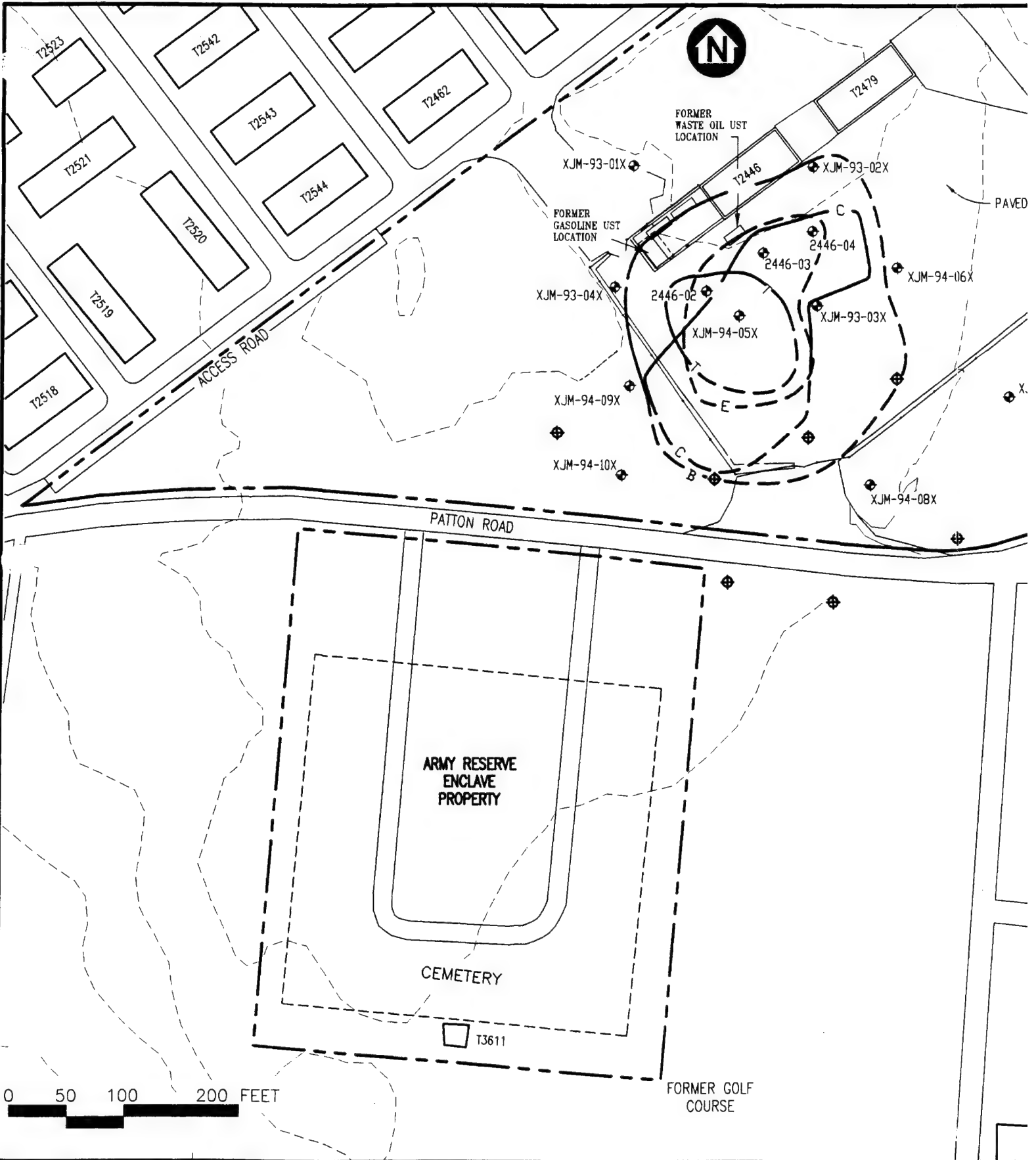
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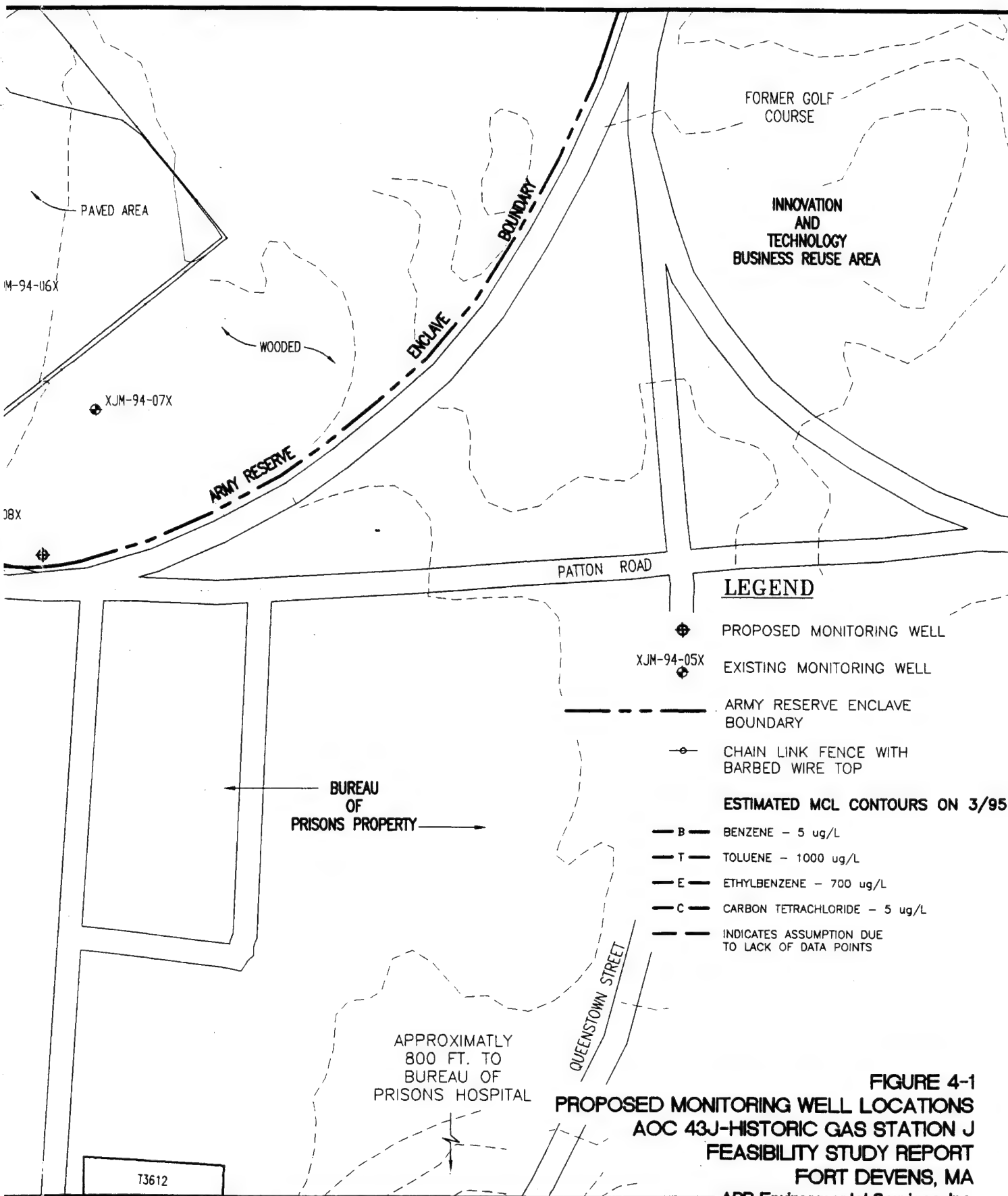
period. O&M costs included for Alternative 4 also apply to Alternative 5.
Table 4-11 summarizes the cost estimate for Alternative 5.

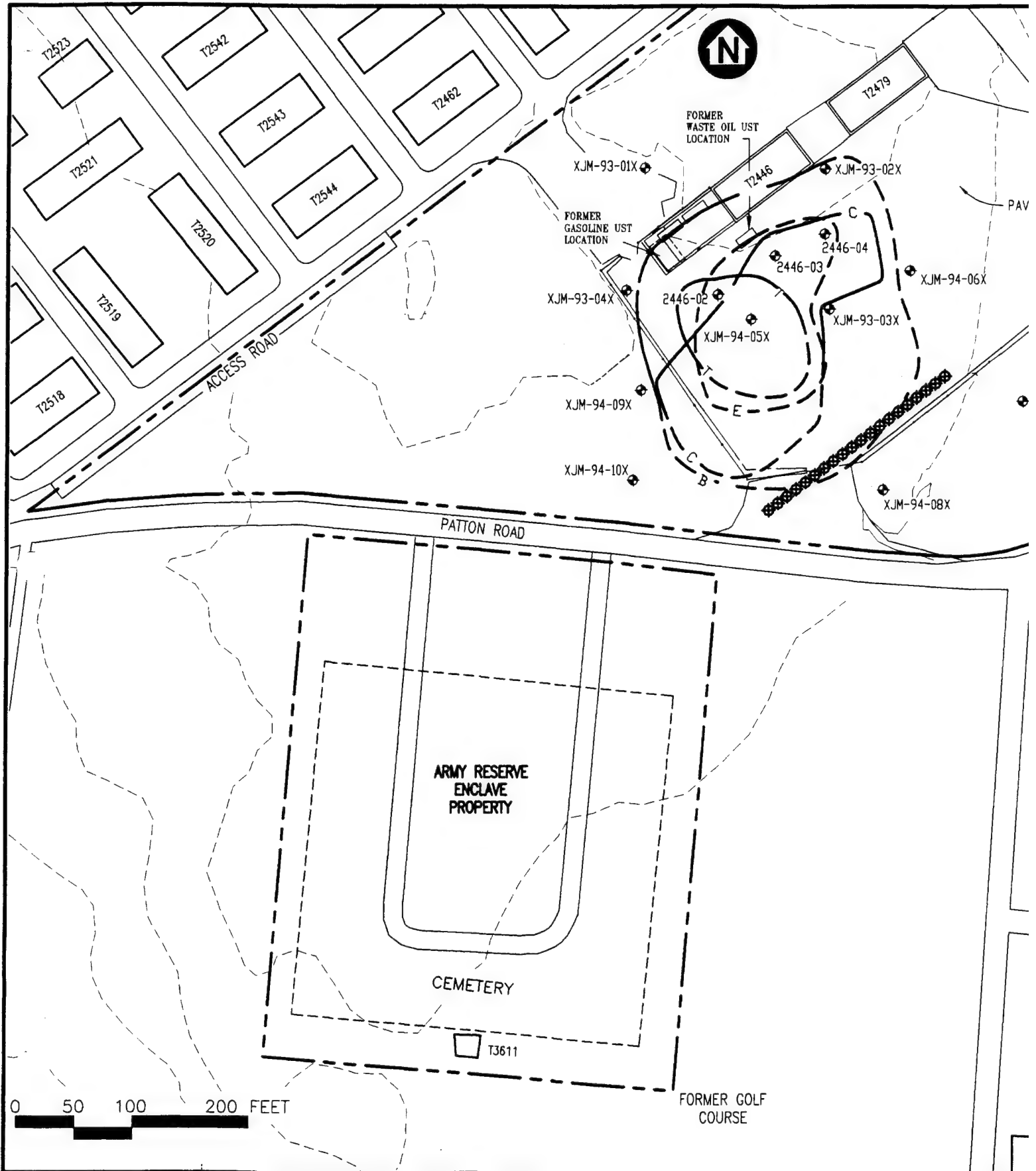
Total Direct and Indirect Costs: \$388,000

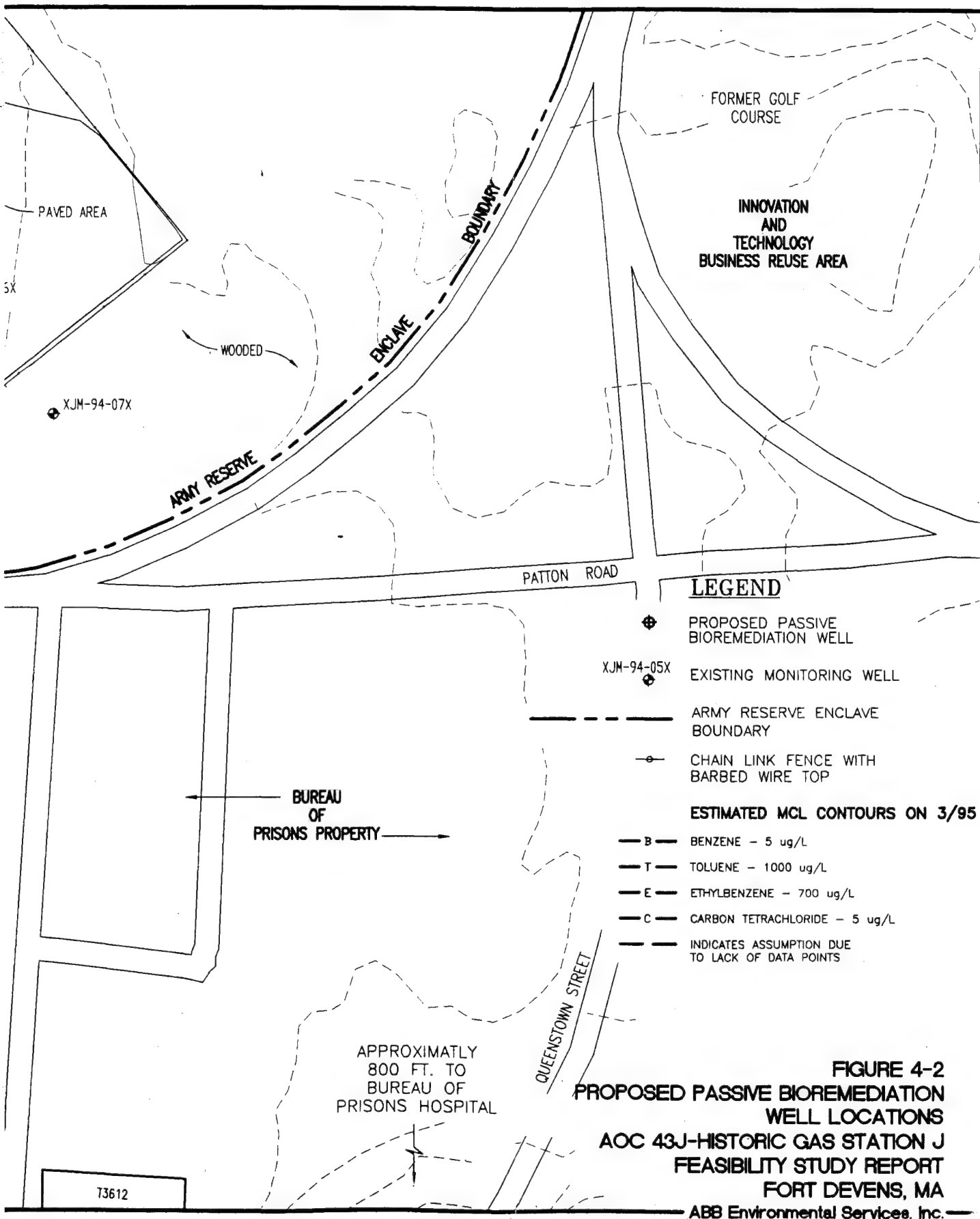
Present Worth of O&M costs: \$1,489,900

Total Present Worth: \$1,877,900 (27 years treatment / 29 years monitoring)









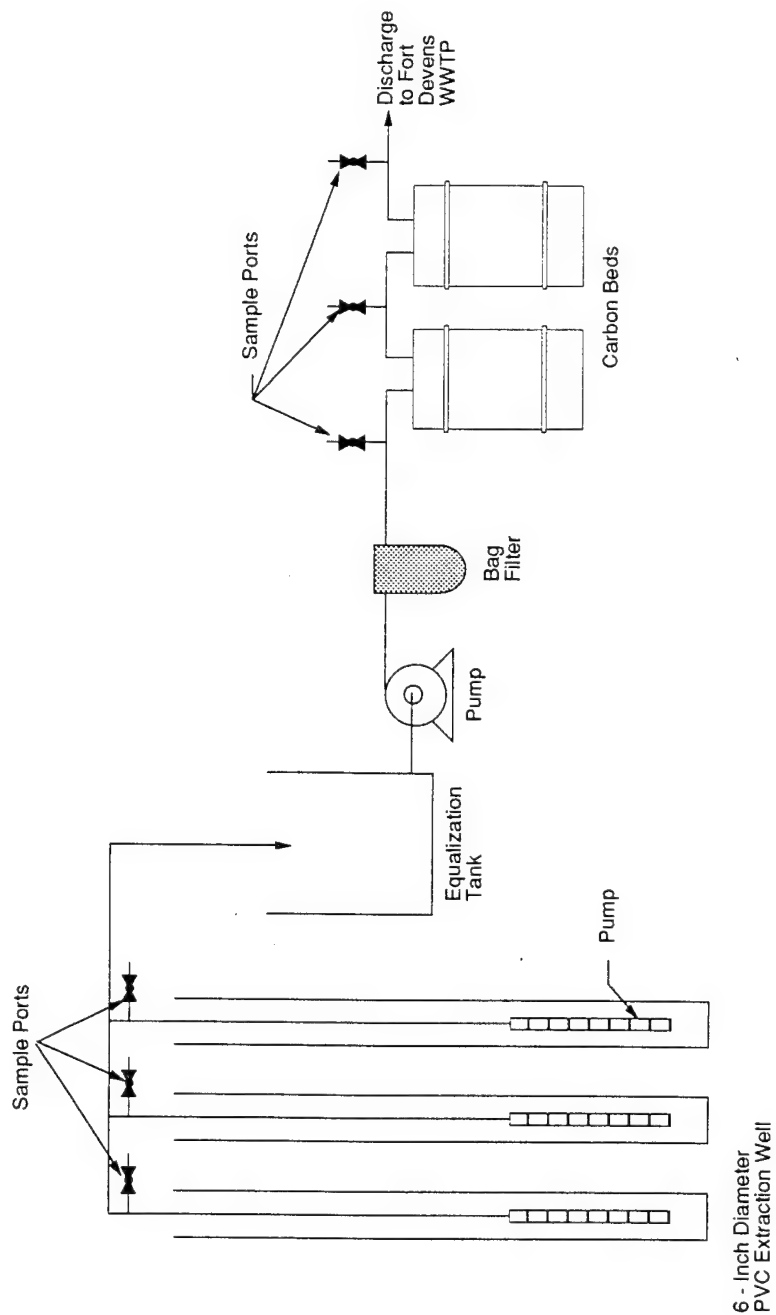
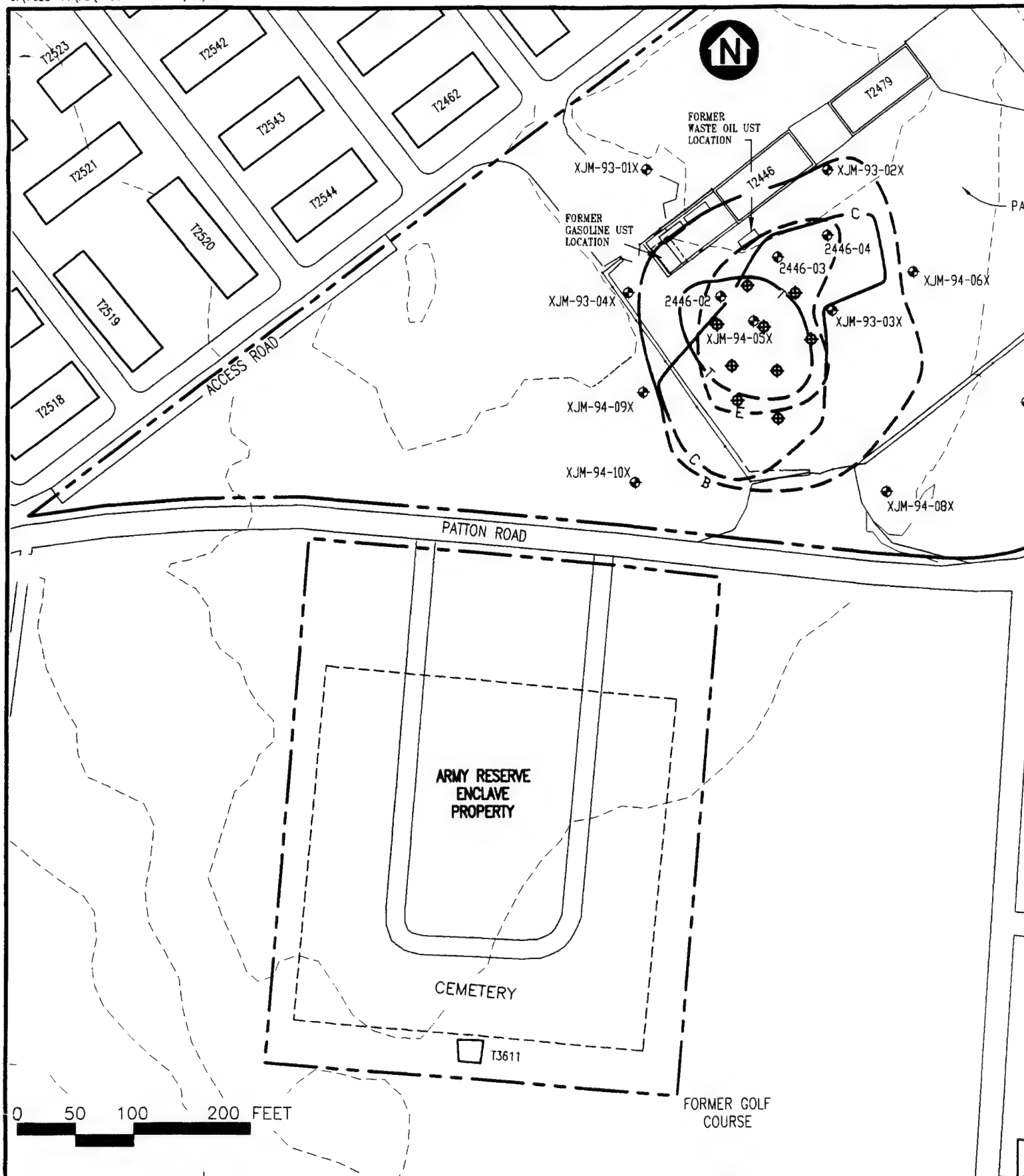


FIGURE 4-3
PROCESS FLOW DIAGRAM - GROUNDWATER TREATMENT
AOC 43J - HISTORIC GAS STATION J
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FORT DEVENS, MA
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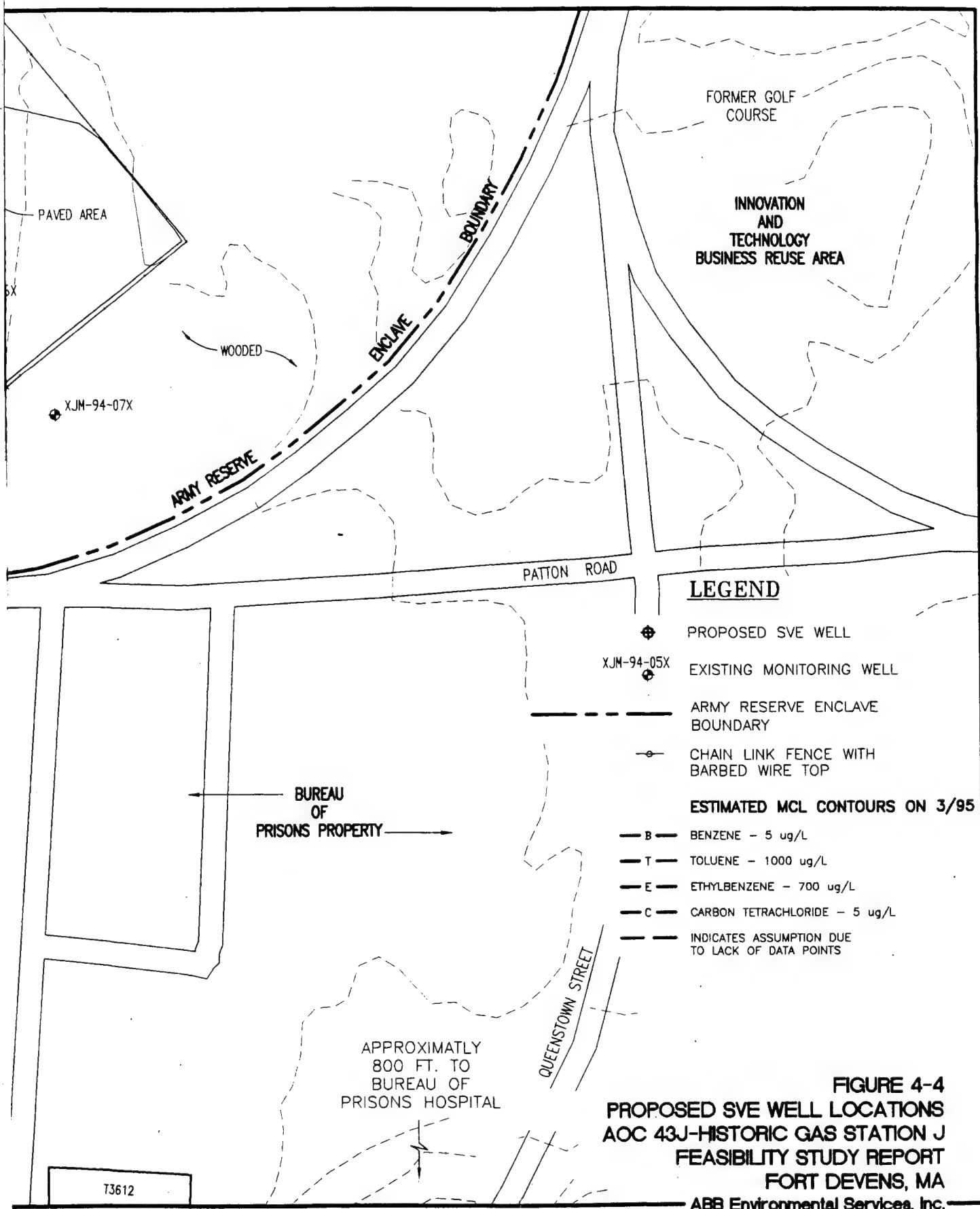


TABLE 4-1
ALTERNATIVE EVALUATION CRITERIA
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THRESHOLD CRITERIA (must be met by each alternative)

- OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT - Assesses how well an alternative, as a whole, achieves and maintains protection of human health and the environment.
- COMPLIANCE WITH ARARS - Assesses how the alternative complies with location-, chemical-, and action-specific ARARs, and whether a waiver is required or justified.

PRIMARY CRITERIA (basis of alternative evaluation)

- LONG-TERM EFFECTIVENESS AND PERMANENCE - Evaluates the effectiveness of the alternative in protecting human health and the environment after response objectives have been met. Includes consideration of the magnitude of residual risks and the adequacy and reliability of controls.
- REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT - Evaluates the effectiveness of treatment processes used to reduce toxicity, mobility, and volume of hazardous substances. This criterion considers the degree to which treatment is irreversible, and the type and quantity of residuals remaining after treatment.
- SHORT-TERM EFFECTIVENESS - Examines the effectiveness of the alternative in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met. Considers the protection of the community, workers, and the environment during implementation of remedial actions.
- IMPLEMENTABILITY - Assesses the technical and administrative feasibility of an alternative and availability of required goods and services. Technical feasibility considers the ability to construct and operate a technology and its reliability, the ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of a remedy. Administrative feasibility considers the ability to obtain approvals from other parties or agencies and extent of required coordination with other parties or agencies.
- COST - Evaluates the capital and operation and maintenance cost of each alternative.

BALANCING CRITERIA

- STATE ACCEPTANCE - This criterion considers the state's preferences among or concerns about alternatives.
- COMMUNITY ACCEPTANCE - This criterion considers the communities preferences among or concerns about alternatives.

TABLE 4-2
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 1:
NO ACTION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority		No location-specific ARARs will be triggered.			
State Regulatory Authority		No location-specific ARARs will be triggered.			

TABLE 4-2
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 1:
NO ACTION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority	Groundwater	SDWA, National Primary Drinking Water Standards, MCLs [40 CFR Parts 141.11 - 141.16 and 141.50 - 141.53]	Relevant and Appropriate	The NPDWR establishes MCLs for several common organic and inorganic contaminants. MCLs specify the maximum permissible concentrations of contaminants in public drinking water supplies. MCLs are federally enforceable standards based in part on the availability and cost of treatment techniques.	Biodegradation of organic contaminants exceeding MCLs is believed to be occurring under existing conditions. However, no monitoring activities will occur to evaluate compliance with these requirements.

TABLE 4-2
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 1:
No ACTION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
State Regulatory Authority	Groundwater	Massachusetts Groundwater Quality Standards [314 CMR 6.00]	Applicable	Massachusetts Groundwater Quality Standards designate and assign uses for which groundwater of the Commonwealth shall be maintained and protected and set forth water quality criteria necessary to maintain the designated uses. Groundwater at Fort Devens is classified as Class 1. Groundwater assigned to this class are fresh groundwater designated as a source of potable water supply.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. However, no monitoring activities will occur to evaluate compliance with these requirements.

TABLE 4-2
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 1:
NO ACTION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
	Groundwater	Massachusetts Drinking Water Standards and Guidelines [310 CMR 22.0].	Relevant and Appropriate	The Massachusetts Drinking Water Standards and Guidelines list MMCLs which apply to water delivered to any user of a public water supply system as defined in 310 CMR 22.00. Private residential wells are not subject to the requirements of 310 CMR 22.00; however, the standards are often used to evaluate private residential contamination especially in CERCLA activities.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. However, no monitoring activities will occur to evaluate compliance with these requirements.

(continued)

TABLE 4-2
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 1:
NO ACTION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	ACTION	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority		No action-specific ARARs will be triggered.			
State Regulatory Authority		No action-specific ARARs will be triggered.			

Notes:

CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
MCLs = Maximum Contaminant Level
MMCLs = Massachusetts Maximum Contaminant Levels

NPDWR = National Primary Drinking Water Standards
SDWA = Safe Drinking Water Act

TABLE 4-3
INTRINSIC BIOREMEDIATION SAMPLING PARAMETERS
AOC 43J

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PARAMETER	PURPOSE
DISSOLVED OXYGEN	defines zone of potential aerobic activity (greater than 0.5 mg/l)
REDOX (Eh)	define/confirm type of microbiological respiration process occurring
NITRATE	electron acceptor for anaerobic microbial respiration, microbial nutrient
NITRITE	electron acceptor for anaerobic microbial respiration, microbial nutrient
PHOSPHATE	microbial nutrient
SULFATE	electron acceptor for anaerobic microbial respiration
SULFIDE	product of sulfate-based microbial respiration
TOTAL IRON	provides indication of anaerobic microbial respiration potential (compared to filtered iron)
SOLUBLE IRON [FE(II)]	product of anaerobic biodegradation (compared to unfiltered iron)
METHANE	product of carbonate-based (CO ₂) microbial respiration (anaerobic degradation of carbon at redox less than -200 mV)
BENZENE, TOLUENE, ETHYLBENZENE, AND CARBON TETRACHLORIDE	Compare to PRGs
ARSENIC, IRON AND MANGANESE (filtered)	Compare to PRGs
TEMPERATURE	well development/purge parameter
pH	aquifer environment condition indicator
CONDUCTIVITY	well development/purge parameter
ALKALINITY	well development/purge parameter
AMMONIA-NITROGEN	microbial nutrient, preliminary form of nitrite/nitrate under aerobic conditions

TABLE 4-4
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 2:
INTRINSIC BIOREMEDIATION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority		No location-specific ARARs will be triggered.			
State Regulatory Authority		No location-specific ARARs will be triggered.			

TABLE 4-4
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 2:
INTRINSIC BIOREMEDIATION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority	Groundwater	SDWA, National Primary Drinking Water Standards, MCLs [40 CFR Parts 141.11 - 141.16 and 141.50 - 141.53]	Relevant and Appropriate	The NPDWR establishes MCLs for several common organic and inorganic contaminants. MCLs specify the maximum permissible concentrations of contaminants in public drinking water supplies. MCLs are federally enforceable standards based in part on the availability and cost of treatment techniques.	Biodegradation of organic contaminants exceeding MCLs is believed to be occurring under existing conditions. MCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.

TABLE 4-4
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 2:
INTRINSIC BIOREMEDIATION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
State Regulatory Authority	Groundwater	Massachusetts Groundwater Quality Standards [314 CMR 6.00]	Applicable	Massachusetts Groundwater Quality Standards designate and assign uses for which groundwater of the Commonwealth shall be maintained and protected and set forth water quality criteria necessary to maintain the designated uses. Groundwater at Fort Devens is classified as Class 1. Groundwater assigned to this class are fresh groundwater designated as a source of potable water supply.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. MMCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.
	Groundwater	Massachusetts Drinking Water Standards and Guidelines [310 CMR 22.0].	Relevant and Appropriate	The Massachusetts Drinking Water Standards and Guidelines list MMCLs which apply to water delivered to any user of a public water supply system as defined in 310 CMR 22.00. Private residential wells are not subject to the requirements of 310 CMR 22.00; however, the standards are often used to evaluate private residential contamination especially in CERCLA activities.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. MMCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.

(continued)

TABLE 4-4
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 2:
INTRINSIC BIOREMEDIATION
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	ACTION	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority		No action-specific ARARs will be triggered.			
State Regulatory Authority	Groundwater Monitoring	Massachusetts Hazardous Waste Management Rules (MHW/MR) Groundwater Protection; [310 CMR 30.660-30.679]	Relevant and Appropriate	Groundwater monitoring is required during and following remedial actions.	A long-term groundwater monitoring program is to be implemented to monitor the progress of remediation.

Notes:

CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
MCLs = Maximum Contaminant Levels
MHW/MR = Massachusetts Hazardous Waste Management Rules

MMCLs = Massachusetts Maximum Contaminant Levels
NPDWR = National Primary Drinking Water Standards
SDWA = Safe Drinking Water Act

TABLE 4-5
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 3:
INTRINSIC BIOREMEDIATION/PASSIVE IN-SITU BIOREMEDIATION CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority		No location-specific ARARs will be triggered.			
State Regulatory Authority		No location-specific ARARs will be triggered.			

TABLE 4-5
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 3:
INTRINSIC BIOREMEDIATION/PASSIVE IN-SITU BIOREMEDIATION CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority	Groundwater	SDWA, National Primary Drinking Water Standards, MCLs [40 CFR Parts 141.11 - 141.16 and 141.50 - 141.53]	Relevant and Appropriate	The NPDWR establishes MCLs for several common organic and inorganic contaminants. MCLs specify the maximum permissible concentrations of contaminants in public drinking water supplies. MCLs are federally enforceable standards based in part on the availability and cost of treatment techniques.	Biodegradation of organic contaminants exceeding MCLs is believed to be occurring under existing conditions. MCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.

TABLE 4-5
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 3:
INTRINSIC BIOREMEDIATION/PASSIVE IN-SITU BIOREMEDIATION CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
State Regulatory Authority	Groundwater	Massachusetts Groundwater Quality Standards [314 CMR 6.00]	Applicable	Massachusetts Groundwater Quality Standards designate and assign uses for which groundwater of the Commonwealth shall be maintained and protected and set forth water quality criteria necessary to maintain the designated uses. Groundwater at Fort Devens is classified as Class 1. Groundwater assigned to this class are fresh groundwater designated as a source of potable water supply.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. MMCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.
	Groundwater	Massachusetts Drinking Water Standards and Guidelines [310 CMR 22.0].	Relevant and Appropriate	The Massachusetts Drinking Water Standards and Guidelines list MMCLs which apply to water delivered to any user of a public water supply system as defined in 310 CMR 22.00. Private residential wells are not subject to the requirements of 310 CMR 22.00; however, the standards are often used to evaluate private residential contamination especially in CERCLA activities.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. MMCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.

(continued)

TABLE 4-5
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 3:
INTRINSIC BIOREMEDIATION/PASSIVE IN-SITU BIOREMEDIATION CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	ACTION	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority	Passive Oxygenation of Groundwater	Underground Injection Control Program [40 CFR Parts 144 & 146]	Relevant and Appropriate	Provides for protection of underground sources of drinking water and technical requirements for compliance. Applicable to underground injection of wastes and contaminated water.	Relevant portions of the regulation will be met through engineering controls.
State Regulatory Authority	Groundwater Monitoring	Massachusetts Hazardous Waste Management Rules (MHWMR) Groundwater Protection; [310 CMR 30.660-30.679]	Relevant and Appropriate	Groundwater monitoring is required during and following remedial actions.	A long-term groundwater monitoring program is to be implemented to monitor the progress of remediation.

(continued)

TABLE 4-5
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 3:
INTRINSIC BIOREMEDIATION/PASSIVE IN-SITU BIOREMEDIATION CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	ACTION	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
State Regulatory Authority	Passive Oxygenation of Groundwater	Underground Water Source Protection [310 CMR 27.00]	Relevant and Appropriate	Regulates any underground injection of hazardous wastes and other fluids with potential to contaminate groundwater. Provides for protection of underground sources of drinking water and technical requirements for compliance.	Relevant portions of the regulations will be met through engineering controls.

Notes:

CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
MCLs = Maximum Contaminant Levels
MHWMR = Massachusetts Hazardous Waste Management Rules

MMCLs = Massachusetts Maximum Contaminant Levels
NPDWR = National Primary Drinking Water Standards
SDWA = Safe Drinking Water Act

TABLE 4-6
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 4:
INTRINSIC BIOREMEDIATION/HYDRAULIC CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority		No location-specific ARARs will be triggered.			
State Regulatory Authority		No location-specific ARARs will be triggered.			

TABLE 4-6
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 4:
INTRINSIC BIOREMEDIATION/HYDRAULIC CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority	Groundwater	SDWA, National Primary Drinking Water Standards, MCLs [40 CFR Parts 141.11 - 141.16 and 141.50 - 141.53]	Relevant and Appropriate	The NPDWR establishes MCLs for several common organic and inorganic contaminants. MCLs specify the maximum permissible concentrations of contaminants in public drinking water supplies. MCLs are federally enforceable standards based in part on the availability and cost of treatment techniques.	Biodegradation of organic contaminants exceeding MCLs is believed to be occurring under existing conditions. MCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.
State Regulatory Authority	Groundwater	Massachusetts Groundwater Quality Standards [314 CMR 6.00]	Applicable	Massachusetts Groundwater Quality Standards designate and assign uses for which groundwater of the Commonwealth shall be maintained and protected and set forth water quality criteria necessary to maintain the designated uses. Groundwater at Fort Devens is classified as Class 1. Groundwater assigned to this class are fresh groundwater designated as a source of potable water supply.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. MMCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.

TABLE 4-6
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 4:
INTRINSIC BIOREMEDIATION/HYDRAULIC CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
	Groundwater	Massachusetts Drinking Water Standards and Guidelines [310 CMR 22.0].	Relevant and Appropriate	The Massachusetts Drinking Water Standards and Guidelines list MMCLs which apply to water delivered to any user of a public water supply system as defined in 310 CMR 22.00. Private residential wells are not subject to the requirements of 310 CMR 22.00; however, the standards are often used to evaluate private residential contamination especially in CERCLA activities.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. MMCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.

(continued)

TABLE 4-6
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 4:
INTRINSIC BIOREMEDIATION/HYDRAULIC CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	ACTION	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority	Discharge to POTW.	CWA, General Pretreatment Program [40 CFR Part 403]	Applicable	Discharges of nondomestic wastewater to POTWs must comply with the general prohibitions of this regulation, as well as categorical standards, and local pretreatment standards.	Discharge to POTW would be sampled to evaluate compliance with pre-treatment standards.
	Disposal of treatment residues	RCRA, Land Disposal Restrictions [40 CFR 268]	Applicable	Land disposal of RCRA hazardous wastes without specified treatment is restricted. LDRs require that wastes must be treated either by a treatment technology or to a specific concentration prior to disposal in a RCRA Subtitle C permitted facility.	Sludge and filtered material from inorganic pretreatment would be tested to evaluate if they are classified as a characteristic hazardous waste for proper disposal.

(continued)

TABLE 4-6
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 4:
INTRINSIC BIOREMEDIATION/HYDRAULIC CONTAINMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	ACTION	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
State Regulatory Authority	Groundwater Monitoring	Massachusetts Hazardous Waste Management Rules (MHW/MR) Groundwater Protection; [310 CMR 30.660-30.679]	Relevant and Appropriate	Groundwater monitoring is required during and following remedial actions.	A long-term groundwater monitoring program is to be implemented to monitor the progress of remediation.
	Excavation/construction	Massachusetts Air Pollution Control Regulations [310 CMR 6.00 - 7.00]	Applicable	Particulate emissions from site activities must not exceed an annual geometric mean of 50 g/m ³ and a maximum 24-hour concentration of 150 mg/m ³ (primary standard). Carbon monoxide, nitrogen dioxide, and lead are also regulated.	Emissions will be managed through engineering controls.

Notes:

CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
CWA = Clean Water Act
LDRs = Land Disposal Restrictions
MHW/MR = Massachusetts Hazardous Waste Management Rules

MMCLs = Massachusetts Maximum Contaminant Levels
NPDES = National Pollutant Discharge Elimination System
NPDWR = National Primary Drinking Water Standards
POTW = Publicly Owned Treatment Works
RCRA = Resource Conservation and Recovery Act
SDWA = Safe Drinking Water Act

TABLE 4-7
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 5:
GROUNDWATER COLLECTION AND TREATMENT/SOIL TREATMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	LOCATION CHARACTERISTIC	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority		No location-specific ARARs will be triggered.			
State Regulatory Authority		No location-specific ARARs will be triggered.			

TABLE 4-7
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 5:
GROUNDWATER COLLECTION AND TREATMENT/SOIL TREATMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority	Groundwater	SDWA, National Primary Drinking Water Standards, MCLs [40 CFR Parts 141.11 - 141.16 and 141.50 - 141.53]	Relevant and Appropriate	The NPDWR establishes MCLs for several common organic and inorganic contaminants. MCLs specify the maximum permissible concentrations of contaminants in public drinking water supplies. MCLs are federally enforceable standards based in part on the availability and cost of treatment techniques.	Biodegradation of organic contaminants exceeding MCLs is believed to be occurring under existing conditions. MCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.

TABLE 4-7
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 5:
GROUNDWATER COLLECTION AND TREATMENT/SOIL TREATMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	CHEMICAL MEDIUM	REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
State Regulatory Authority	Groundwater	Massachusetts Groundwater Quality Standards [314 CMR 6.00]	Applicable	Massachusetts Groundwater Quality Standards designate and assign uses for which groundwater of the Commonwealth shall be maintained and protected and set forth water quality criteria necessary to maintain the designated uses. Groundwater at Fort Devens is classified as Class 1. Groundwater assigned to this class are fresh groundwater designated as a source of potable water supply.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. MMCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.
	Groundwater	Massachusetts Drinking Water Standards and Guidelines [310 CMR 22.0].	Relevant and Appropriate	The Massachusetts Drinking Water Standards and Guidelines list MMCLs which apply to water delivered to any user of a public water supply system as defined in 310 CMR 22.00. Private residential wells are not subject to the requirements of 310 CMR 22.00; however, the standards are often used to evaluate private residential contamination especially in CERCLA activities.	Biodegradation of organic contaminants exceeding MMCLs is believed to be occurring under existing conditions. MMCLs will be used to evaluate the performance of this alternative through implementation of a long-term groundwater monitoring program.

TABLE 4-7
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 5:
GROUNDWATER COLLECTION AND TREATMENT/SOIL TREATMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	ACTION	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
Federal Regulatory Authority	Discharge to POTW.	CWA, General Pretreatment Program [40 CFR Part 403]	Applicable	Discharges of nondomestic wastewater to POTWs must comply with the general prohibitions of this regulation, as well as categorical standards, and local pretreatment standards.	Discharge to POTW would be sampled to evaluate compliance with pre-treatment standards.
	Disposal of treatment residues	RCRA, Land Disposal Restrictions [40 CFR 268]	Applicable	Land disposal of RCRA hazardous wastes without specified treatment is restricted. LDRs require that wastes must be treated either by a treatment technology or to a specific concentration prior to disposal in a RCRA Subtitle C permitted facility.	Sludge and filtered material from inorganic pretreatment would be tested to evaluate if they are classified as a characteristic hazardous waste for proper disposal.
State Regulatory Authority	Groundwater Monitoring	Massachusetts Hazardous Waste Management Rules (MHWMR) Groundwater Protection; [310 CMR 30.660-30.679]	Relevant and Appropriate	Groundwater monitoring is required during and following remedial actions.	A long-term groundwater monitoring program is to be implemented to monitor the progress of remediation.

TABLE 4-7
SYNOPSIS OF FEDERAL AND STATE ARARS FOR ALTERNATIVE 5:
GROUNDWATER COLLECTION AND TREATMENT/SOIL TREATMENT
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

AUTHORITY	ACTION	REQUIREMENTS	STATUS	REQUIREMENT SYNOPSIS	ACTION TO BE TAKEN TO ATTAIN REQUIREMENT
	Excavation/ construction and SVE treatment	Massachusetts Air Pollution Control Regulations [310 CMR 6.00 - 7.00]	Applicable	Particulate emissions from site activities must not exceed an annual geometric mean of 50 g/m ³ and a maximum 24-hour concentration of 150 mg/m ³ (primary standard). Carbon monoxide, nitrogen dioxide, and lead are also regulated. SVE system must reduce VOCs in air effluent stream by at least 95% by weight.	Emissions will be managed through engineering controls.

Notes:

BACT = Best Available Control Technology
 CERCLA = Comprehensive Environmental Response, Compensation and
 Liability Act
 CWA = Clean Water Act
 LDRs = Land Disposal Restrictions
 MCLs = Maximum Contaminant Levels
 MHWMR = Massachusetts Hazardous Waste Management Rules
 MMCLs = Massachusetts Maximum Contaminant Levels
 NPDES = National Pollutant Discharge Elimination System

POTW = Publicly Owned Treatment Works
 RCRA = Resource Conservation and Recovery Act
 SDWA = Safe Drinking Water Act
 SVE = Soil Vapor Extraction
 TAP = Toxic Air Pollutant Control
 VOCs = Volatile Organic Compounds

NPDWR = National Primary Drinking Water Standards

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TABLE 4-8
ALTERNATIVE 2: INTRINSIC BIOREMEDIATION
COST SUMMARY TABLE
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

ITEM	COST
DIRECT COSTS	
Well Construction and Development	\$17,600
INDIRECT COSTS	
Design/Engineering	\$15,000
Construction Oversight/Health and Safety	\$5,200
CAPITAL COST (DIRECT + INDIRECT) SUBTOTAL	\$37,800
UNDEVELOPED DESIGN DETAILS @ 25%	\$9,400
TOTAL CAPITAL COSTS	\$47,200
OPERATION AND MAINTENANCE COSTS	
Analytical	\$9,900
ODCs (sampling equipment, shipping)	\$1,300
Sampling Labor	\$9,400
Engineering/Consulting	\$4,000
YEARLY O&M SUBTOTAL	\$24,600
UNDEVELOPED DESIGN DETAILS @ 25%	\$6,200
TOTAL O&M PRESENT WORTH (P/A, 7% , 27)	\$369,200
5-YEAR SITE REVIEWS (Total Present Worth)	\$21,500
CLOSEOUT GROUNDWATER MONITORING (Total Present Worth)	\$3,800
TOTAL PRESENT WORTH OF ALTERNATIVE 2	\$441,700

TABLE 4-9
**ALTERNATIVE 3: INTRINSIC BIOREMEDIATION/
 PASSIVE IN SITU BIOREMEDIATION CONTAINMENT**
COST SUMMARY TABLE
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

ITEM	COST
DIRECT COSTS	
Well Construction and Development	\$68,300
INDIRECT COSTS	
Design/Engineering	\$21,000
Construction Oversight/Health and Safety/System Startup	\$18,400
CAPITAL COST (DIRECT + INDIRECT) SUBTOTAL	\$107,700
UNDEVELOPED DESIGN DETAILS (25%)	\$26,900
TOTAL CAPITAL COSTS	\$134,600
OPERATION AND MAINTENANCE COSTS	
Field Technician	\$13,000
Oxygen Release Compound/Nutrient Material	\$10,000
Well Maintenance	\$14,000
Engineering/Consulting	\$7,800
Sampling Labor	\$9,400
ODCs (sampling equipment, shipping)	\$1,200
Analytical	\$9,900
YEARLY O&M SUBTOTAL	\$65,300
UNDEVELOPED DESIGN DETAILS (25%)	\$16,300
TOTAL O&M PRESENT WORTH (P/A, 7%, 27 years)	\$978,100
5-YEAR SITE REVIEWS (Total Present Worth)	\$21,500
CLOSEOUT GROUNDWATER MONITORING (Total Present Worth)	\$3,800
TOTAL PRESENT WORTH OF ALTERNATIVE 3	\$1,138,000

TABLE 4-10
ALTERNATIVE 4: INTRINSIC BIOREMEDIATION/HYDRAULIC CONTAINMENT
COST SUMMARY TABLE
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

ITEM	COST
DIRECT COSTS	
Groundwater Recovery System Construction	\$27,500
Groundwater Treatment System Construction	\$52,000
Treatment System Housing	\$26,800
Startup Analytical	\$1,800
INDIRECT COSTS	
Overburden and Bedrock Pumping Tests	\$42,000
Design/Engineering	\$50,000
Construction Oversight/System Startup/Health and	\$16,000
CAPITAL COST (DIRECT + INDIRECT) SUBTO	\$216,100
UNSPECIFIED DESIGN DETAILS (25%)	\$54,000
TOTAL CAPITAL COSTS	\$270,100
OPERATION AND MAINTENANCE COSTS	
Field Technician (GW extraction and treatment)	\$18,700
Analytical (GW treatment system)	\$7,200
ODCs	\$1,200
Power	\$2,400
Carbon System Exchange (GW)	\$26,300
Bag Filter System	\$1,000
Engineering/Consulting	\$14,100
GW Sampling (Labor + Analytical)	\$20,600
YEARLY GW O&M SUBTOTAL	\$91,500
UNSPECIFIED DESIGN DETAILS (25%)	\$22,900
TOTAL O&M PRESENT WORTH (36 yr operation, 27 yr	\$1,382,000
5-YEAR SITE REVIEWS (Total Present Worth)	\$25,100
5-YEAR GEOPROBE SOIL SAMPLING (Each 5 years for	\$18,000
CLOSEOUT GROUNDWATER MONITORING (Total Pr	\$8,600
(Years 27-29 and 36-38)	
TOTAL PRESENT WORTH OF ALTERNATIVE 4	\$1,703,800

TABLE 4-11
ALTERNATIVE 5: GW COLLECTION AND TREATMENT/SOIL TREATMENT
COST SUMMARY TABLE
AOC 43J

FEASIBILITY STUDY REPORT
FORT DEVENS, MA

ITEM	COST
DIRECT COSTS	
Groundwater Recovery System Construction	\$27,500
Groundwater Treatment System Construction	\$52,000
Treatment System Housing	\$26,800
Soil Vapor Extraction System Construction	\$19,700
Soil Vapor Treatment System Construction	\$25,200
Startup Analytical	\$4,000
INDIRECT COSTS	
Overburden and Bedrock Pumping Tests	\$42,000
On-Site Permeability (SVE) Test	\$16,200
Design/Engineering	\$68,000
Construction Oversight/System Startup/Health and Safety	\$29,000
CAPITAL COST (DIRECT + INDIRECT) SUBTOTAL	\$310,400
UNSPECIFIED DESIGN DETAILS (25%)	\$77,600
TOTAL CAPITAL COSTS	\$388,000
OPERATION AND MAINTENANCE COSTS	
Field Technician (GW extraction and treatment)	\$18,700
Analytical (GW treatment system)	\$7,200
ODCs	\$1,200
Power	\$2,400
Carbon System Exchange (GW)	\$26,300
Bag Filter System	\$1,000
Engineering/Consulting	\$14,100
GW Sampling (Labor + Analytical)	\$20,600
YEARLY GW O&M SUBTOTAL	\$91,500
UNSPECIFIED DESIGN DETAILS (25%)	\$22,900
Field Technician (SVE extraction and treatment systems)	\$8,600
Analytical (SVE treatment system)	\$7,200
ODCs (SVE)	\$1,200
Power (SVE System)	\$1,000
Carbon System Exchange (SVE)	\$6,300
Engineering/Reporting (SVE system)	\$12,000
TOTAL O&M PRESENT WORTH (27 years of GW Treat + 2 yrs SVE)	\$1,453,300
5-YEAR SITE REVIEWS (Total Present Worth)	\$21,500
YEAR 3 CLOSEOUT GEOPROBE SOIL SAMPLING (Present Worth)	\$11,300
CLOSEOUT GROUNDWATER MONITORING (Total Present Worth)	\$3,800
TOTAL PRESENT WORTH OF ALTERNATIVE 5	\$1,877,900

5.0 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents a comparison of the five remedial alternatives that were the focus of the detailed evaluation, highlighting the relative advantages and disadvantages of the alternatives with respect to the seven evaluation criterion. The evaluation is performed to assist decision-makers in selecting a remedy that cost-effectively meets the remedial action objectives. The evaluation criteria are divided into three specific categories during remedy selection: Threshold Criteria, Primary Balancing Criteria, and Modifying Criteria. Threshold criteria include Overall Protection of Human Health and the Environment, and Compliance with ARARs. Alternatives must meet threshold criteria to be chosen as the selected remedy. Primary balancing criteria include: Long-term Effectiveness and Permanence; Reduction of Toxicity, Mobility, and Volume through Treatment; Short-term Effectiveness; Implementability; and Cost. These seven criteria are used in this section to compare the alternatives. Modifying criteria include state and community acceptance, and will be addressed in the Record of Decision.

The five remedial alternatives that are the focus of the detailed analysis are:

- Alternative 1: No Action
- Alternative 2: Intrinsic Bioremediation
- Alternative 3: Intrinsic Bioremediation/Passive In-Situ Bioremedial Containment
- Alternative 4: Intrinsic Bioremediation/Hydraulic Containment
- Alternative 5: Groundwater Collection and Treatment/Soil Treatment

Results of the evaluation are summarized in Table 5-1.

SECTION 5

5.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

This criteria, according to CERCLA, must be met for a remedial alternative to be chosen as a final site remedy. At AOC 43J groundwater sampling has shown that contaminants exceed PRGs on Army Reserve Enclave property; however, no current commercial or industrial exposure to groundwater exists because there are no drinking water wells installed on site. Also, no future exposure to groundwater on site is anticipated. The site is to remain Army property and will continue to be used to support Army Reserve activities. There are no future plans to install water supply wells on site to support these activities. Groundwater analysis results indicate that intrinsic biodegradation is currently occurring naturally at AOC 43J.

Calculations indicate that organic CPCs will be reduced below PRGs over time as a result of the intrinsic biodegradation process. Calculations also reveal that concentrations exceeding PRGs will not likely migrate beyond the Army Reserve Enclave boundary, thereby protecting downgradient receptors from future exposure to CPCs. Because intrinsic biodegradation is a naturally occurring process, all alternatives consider it as a remedial component. However, the degree to which each alternative relies on intrinsic bioremediation varies. Some of the alternatives rely on redundant or backup components to achieve PRGs if intrinsic biodegradation does not perform as anticipated. Therefore, all alternatives are considered protective of human health and the environment.

Although Alternative 1 proposes no action, intrinsic bioremediation would likely result in attainment of PRGs. However, there would be no method to assess the protectiveness of this alternative because there would be no groundwater monitoring performed. Alternative 2 would use additional data collection, modeling, long-term groundwater monitoring, five-year site reviews and contingencies for additional action to ensure that intrinsic bioremediation is protective of human health and the environment. Alternatives 3, 4 and 5 add more active response actions as redundant or backup components in addition to their reliance on intrinsic bioremediation. Alternative 3 adds passive bioremediation (aerobic treatment) at the plume edge to minimize migration potential. Alternatives 4 and 5 add groundwater extraction/treatment and groundwater extraction/treatment combined with SVE, respectively. The added technologies in Alternatives 3, 4, and 5 increase the potential protection of downgradient receptors, although each could also be added as contingency alternatives upon nonperformance of intrinsic biodegradation, outlined in

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Alternative 2, without jeopardizing overall protection of human health and the environment.

5.2 COMPLIANCE WITH ARARS

CERCLA requires that the selected alternative also meet a second threshold criterion of compliance with ARARs, or obtain a waiver if the criterion can not be met. No location-specific ARARs are triggered for remedial activities at AOC 43J. All alternatives rely on intrinsic bioremediation to comply with chemical-specific ARARs within the mitigation time-frames presented for each alternative. (Groundwater extraction and treatment without considering intrinsic biodegradation would require a longer time-frame to comply with ARARs). Organic CPC concentrations will be reduced to below MCLs and MMCLs by biological degradation. Inorganic CPCs in groundwater will revert to more insoluble forms upon reduction of organic concentrations and meet MCLs and MMCLs, and the Massachusetts Groundwater Quality Criteria (314 CMR 6.00).

Alternatives 2 through 5 would use groundwater monitoring to evaluate long-term effectiveness and the potential for CPC migration off Army Reserve Enclave property. Monitoring would be in compliance with substantive portions of the Massachusetts Hazardous Waste Management Rules 310 CMR 30.660 - 30.670 relating to the development of a groundwater monitoring plan. Alternatives 3 through 5 would need to meet additional action-specific ARARs because of the additional technologies used. Alternative 3 would be in general compliance with the Underground Injection Control Program (40 CFR Parts 144 & 146) and Underground Water Source Protection Standards (310 CMR 27.00). Alternative 4 groundwater treatment discharge would meet the requirements of the Clean Water Act, General Pretreatment Program (40 CFR Part 403). Treatment wastes (i.e., activated carbon, filtered material, and sludge) would be tested to evaluate if they are classified as a characteristic hazardous waste in accordance with RCRA Land Disposal Restrictions (40 CFR 268). Engineering controls (dust suppression) would be used to comply with Massachusetts Air Pollution Control Regulations (310 CMR 6.00 - 7.00) which would regulate particulate emissions during site construction activities. Alternative 5 would use a soil venting gas treatment system to comply with the Massachusetts Air Pollution Control regulations (310 CMR 7.03). For costing purposes in this FS evaluation, soil venting gas treatment by vapor phase activated carbon was assumed. The air

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SECTION 5

regulations require a minimum 95 percent reduction (by weight) in VOCs in the air effluent stream. Air monitoring would be required to ensure compliance.

5.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

This criterion evaluates the magnitude of residual risk and the reliability of controls after response objectives have been met. Alternative 2, as well as all the other alternatives rely on intrinsic bioremediation to achieve the remedial action objectives within the mitigation time-frames presented for each alternative. In the microbial degradation process of intrinsic bioremediation, the organic CPCs are ultimately converted to inert compounds such as carbon dioxide, methane, and water. Inorganic CPCs revert to more insoluble forms following completion of organic degradation. Because of the degradation/destruction of organic contaminants that occurs in this process, intrinsic bioremediation provides permanent treatment effectiveness without secondary waste disposal. Alternative 3 offers no real long-term advantages over Alternative 2. Once PRGs are achieved, bioremediation wells would no longer be used to add oxygen-releasing compounds and nutrients. Alternatives 4 and 5 which use backup technologies of groundwater extraction and treatment and SVE have secondary waste (i.e., activated carbon and sludge) that will require disposal.

Alternatives 4 and 5 would lower the groundwater table by approximately 1 foot. The potential for groundwater recontamination exists when the groundwater table rebounds after groundwater extraction has been halted (if the contamination in the vadose zone soil is not reduced). Soil sampling/monitoring would be performed to evaluate the progressiveness of biodegradation and SVE in the vadose zone for Alternatives 4 and 5, respectively. Any remaining soil contamination may be difficult to detect because of the heterogenous nature of soil and contaminant distribution.

Alternatives 2 and 3 do not lower the groundwater table so the potential for groundwater recontamination is not as likely. All alternatives, except Alternative 1, use long-term groundwater monitoring to ensure that compliance with PRGs is reached for three consecutive annual sampling rounds.

5.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

This criterion evaluates whether the alternatives meet the statutory preference for treatment under CERCLA. The criterion evaluates the reduction of toxicity, mobility, or volume of contaminants, and the type and quantity of treatment residuals. All alternatives, including Alternative 1 (No Action), meet the statutory preference for treatment under CERCLA because intrinsic bioremediation is a naturally occurring process for all alternatives evaluated. Alternatives 3, 4 and 5 offer back-up treatment processes which also contribute to the reduction of toxicity, mobility, and volume of contaminants.

Alternatives 4 and 5 would generate concentrated waste streams (i.e., sludge, filtered material, and spent carbon) that would require disposal.

5.5 SHORT-TERM EFFECTIVENESS

CERCLA requires that potential adverse short-term effects to workers, the surrounding community, and the environment be considered during selection of a remedial action. Major adverse short-term effects to site workers are not expected for any of the alternatives because all activities can be readily monitored and engineering control implemented in accordance with a Health and Safety Plan. However, because of more intrusive activities, monitoring requirements and construction work, the potential for contaminant exposure and safety hazards to workers increases with Alternatives 2, 3, 4 and 5, respectively. Alternative 3 requires installation of over six times the number of wells required by Alternative 2. Alternatives 4 and 5 utilize active treatment processes that require more frequent contact with contaminated medium during O&M and monitoring activities.

Alternatives 1, 2, 3, and 5 are expected to require 27 years to meet remedial objectives. Alternative 4 is anticipated to require 36 years to meet remedial objectives. (Remedial times are not inclusive of the additional two years of groundwater monitoring required for Alternatives 2 through 5.)

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5.6 IMPLEMENTABILITY

This criterion evaluates each alternative's ease of construction and operation and availability of services, equipment, and materials to construct and operate the alternative. Also evaluated is the ease of undertaking additional remedial actions and administrative feasibility.

Although the engineering complexity increases for each alternative (i.e., Alternative 5 > Alternative 4 > Alternative 3 > Alternative 2 > Alternative 1), engineering and construction services, equipment, and materials should be readily available to implement any of the alternatives. Alternatives 2 through 5 all require additional data collection, modeling or pilot testing prior to design and implementation. Alternatives 2 and 3 would require additional data collection and intrinsic bioremediation modeling. Alternative 3 would also require, as a minimum, laboratory treatability testing to assess oxygen-releasing compounds and nutrient needs. Limited pilot testing may also be required to verify field application of oxygen-releasing compounds and nutrients. Alternatives 4 and 5 both require groundwater pumping tests and hydrogeological modeling to verify flow rates and quantity and placement of extraction wells to hydraulically contain the contaminant plume. Alternative 5 also requires performing an SVE pilot test to collect needed design parameters.

Groundwater monitoring to assess the success of remedial action is performed easily for all alternatives. The soil monitoring that is required to assess the potential for groundwater recontamination in Alternatives 4 and 5 is more difficult to achieve because of the heterogenous soil medium and contaminant distribution.

None of the alternatives would limit or interfere with the ability to perform future remedial actions. All alternatives would require coordination among regulatory agencies to institute the five-year review process.

5.7 COST

There are not costs associated with Alternative 1. Capital, O&M, and present worth costs were estimated for Alternatives 2 through 5. Cost estimates for these alternatives included similar expense for long-term groundwater monitoring. As

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would be expected, Alternatives 2 and 5 are the least and most expensive alternatives, respectively. The alternative with the lowest capital cost is Alternative 2 because it does not include extensive construction activities. Alternative 5 has the highest capital cost because it includes the design and construction of a groundwater extraction/treatment system and SVE system. Alternatives 4 and 5 both have high O&M costs because of long-term maintenance of the groundwater treatment and SVE systems. Alternative 3 also has a relatively high O&M cost because of long-term oxygen-releasing compound application and nutrient addition and well maintenance. Total present worth cost for Alternative 4 was less than Alternative 5 even though remedial action time for Alternative 4 is expected to be nine years longer than for Alternative 5. This is because of the expense for SVE O&M is greater than the O&M costs for operating the extraction system to keep the groundwater table depressed (assumes no groundwater treatment required after 27 years).

After calculating the present worth for each alternative, the sensitivity of the costs to the estimating assumptions was evaluated. The total cost associated with all alternatives consist primarily of long-term O&M and/or groundwater monitoring costs. These long-term costs contribute between 80 percent and 89 percent to the overall total cost. A relative high degree of uncertainty is associated with the length of time required to reduce contaminants to below PRGs. The estimate of 27 years for intrinsic bioremediation is based on very conservative assumptions as detailed in Appendix C. Should ethylbenzene degrade as rapidly as the other organic CPCs, remedial objectives could be met within approximately 10 years. This shortened treatment period would reduce O&M costs and total present worth costs proportionally for all alternatives. Therefore, further sensitivity analysis to assess effects from "across the board" remedial action time reduction was not performed for these alternatives.

However, it is noted that expenses incurred for Alternative 3 assume that oxygen-releasing compounds and nutrient application would be required for the entire 27-year remedial action time period. Numerous other scenarios are equally likely (i.e., biodegradation within the plume area could occur to the extent that the contaminant plume would shrink in size within five years and that maintenance of the bioremediation wells would not be required for the remaining duration of 22 years that it would take to reduce CPCs below PRGs. Reducing need for aerobic treatment time would significantly reduce O&M costs for Alternative 3.

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The total present worth cost could be reduced to approximately 60 percent of the full 27-year total present worth cost (from approximately \$1,140,000 to \$680,000).

5.8 COMPARATIVE ANALYSIS SUMMARY

Alternative 1 is considered equal to Alternative 2 considering threshold criteria except that compliance would not be able to be monitored. Alternative 1 is also considered equal to Alternative 2 considering primary balancing criteria except that there would be no effects to site-workers during remedial implementation or cost associated with implementation of Alternative 1. (There is no active remedial action or monitoring implemented in Alternative 1.)

Alternative 2 is considered equal to Alternatives 3, 4 and 5 considering threshold criteria in that they all are protective of human health and meet ARARs. Alternatives 3, 4, and 5 use redundant or backup components to achieve PRGs. Alternative 2 would rely on additional data collection, modeling, long-term groundwater monitoring, five-year site reviews and contingencies for additional action to ensure that intrinsic bioremediation is protective of human health and the environment. The added treatment technologies in Alternatives 3, 4, and 5 can be interpreted as increasing the protection of downgradient receptors, although each could also be added as contingency alternatives to Alternative 2 upon nonperformance of intrinsic biodegradation without jeopardizing overall protection of human health and the environment.

In general, Alternative 2 is also equal to or better than Alternatives 3, 4, and 5 considering primary balancing criteria. Alternatives 3, 4 and 5 more favorably offer back-up treatment processes which contribute to the reduction of toxicity, mobility and volume of contaminants, although intrinsic biodegradation is considered to be the controlling factor in determining the time required for remedial action. The back-up treatments in Alternatives 4 and 5 would generate concentrated waste streams (sludge, filtered material, spent carbon) that would require disposal. Also, the potential for groundwater re-contamination exists when the groundwater table rebounds after groundwater extraction has been halted for Alternatives 4 and 5. Because of more intrusive activities, monitoring requirements and construction work, the potential for contaminant exposure and safety hazards to workers increases with Alternatives 2, 3, 4 and 5, respectively in order presented. Alternative 2 is expected to take the same number of years for

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remediation as Alternatives 3 and 5 (27 years) and take a shorter time than Alternative 4 (36 years). The engineering complexity increases for each alternative (i.e., Alternative 5 > Alternative 4 > Alternative 3 > Alternative 2). Alternatives 2 through 5 all require additional data collection, modeling or pilot testing prior to design and implementation. Alternative 2 is the least expensive alternative followed by Alternatives 3, 4, and 5, in order of increasing cost.

Alternative 3 is considered equal to Alternatives 4 and 5 when comparing threshold criteria in that they all are protective of human health and meet ARARs. Alternatives 4 and 5 use active redundant or backup treatment components to achieve PRGs if intrinsic biodegradation does not perform as anticipated. Alternative 3 utilizes passive aerobic bioremediation to ensure protection of human health and the environment downgradient of the Army Reserve Enclave boundary. The added active treatment technologies in Alternatives 4 and 5 can be interpreted as increasing the potential protectiveness for downgradient receptors, although each could also be added as contingency alternatives to Alternative 3 upon nonperformance of intrinsic biodegradation without jeopardizing overall protection of human health and the environment. Alternative 3 is also equal to or better than Alternatives 4 and 5 considering primary balancing criteria for similar reasons specified for Alternative 2.

Alternative 4 is considered equal to Alternative 5 considering threshold criteria in that they are both protective of human health and meet ARARs. Alternatives 4 and 5 both use active redundant or backup treatment components to achieve PRGs if intrinsic biodegradation does not perform as anticipated. Alternative 5 uses an active treatment (SVE) to minimize potential groundwater re-contamination upon aquifer rebound following completion of groundwater extraction. The active treatment technology in Alternative 5 can be interpreted as increasing the potential protectiveness for downgradient receptors. However, both alternatives require soil monitoring to assess groundwater re-contamination potential which could be difficult to perform because of the heterogeneous soil medium and contaminant distribution.

Alternative 4 is also considered essentially equal to Alternative 5 considering primary balancing criteria. Alternative 5 more favorably uses the back-up soil treatment process (SVE) which contributes to the reduction of toxicity, mobility and volume of contaminants within a shorter time than Alternative 4. However, additional pilot testing (SVE) is required for Alternative 5. Because of more

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intrusive activities, monitoring requirements and construction work, the potential for contaminant exposure and safety hazards to workers is greater for Alternative 5. Also the overall total present worth cost is greater for Alternative 5 than for Alternative 4.

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ASSESSMENT FACTORS	ALTERNATIVE 1: NO ACTION	ALTERNATIVE 2: INTRINSIC BIOREMEDIATION	ALTERNATIVE 3: INTRINSIC BIOREMEDIATION / PASSIVE IN-SITU BIOREMEDIATION CONTAINMENT	ALTERNATIVE 4: INTRINSIC BIOREMEDIATION / HYDRAULIC CONTAINMENT	ALTERNATIVE 5: GROUNDWATER COLLECTION & TREATMENT / SOIL TREATMENT
<u>Overall Protection of Human Health and the Environment</u>					
<u>Human Health</u>	<ul style="list-style-type: none"> Can potentially reduce future exposure or potential risks by intrinsic bioremediation. No monitoring activities would occur to evaluate human health protection. 	<ul style="list-style-type: none"> Protection of human health provided by intrinsic bioremediation and by implementing a long-term groundwater monitoring program. 	<ul style="list-style-type: none"> Protection of human health provided by intrinsic bioremediation, installing passive bioremediation wells for aerobic biodegradation at the plume edge and by implementing a long-term groundwater monitoring program. 	<ul style="list-style-type: none"> Protection of human health provided by groundwater extraction & treatment and intrinsic bioremediation for hydraulic containment and to reduce contaminant concentrations, SVE to minimize the potential for groundwater recontamination upon aquifer rebound and by implementing a long-term groundwater monitoring program. 	<ul style="list-style-type: none"> Protection of human health provided by groundwater extraction & treatment and intrinsic bioremediation for hydraulic containment and to reduce contaminant concentrations, SVE to minimize the potential for groundwater recontamination upon aquifer rebound and by implementing a long-term groundwater monitoring program.
<u>Environment</u>	<ul style="list-style-type: none"> No ecological exposures at the site. 	<ul style="list-style-type: none"> No ecological exposures at the site. 	<ul style="list-style-type: none"> No ecological exposures at the site. 	<ul style="list-style-type: none"> No ecological exposures at the site. 	<ul style="list-style-type: none"> No ecological exposures at the site.
<u>Compliance with ARARS</u>	<ul style="list-style-type: none"> No location-specific ARARS would be triggered. 	<ul style="list-style-type: none"> No location-specific ARARS would be triggered. 	<ul style="list-style-type: none"> No location-specific ARARS would be triggered. 	<ul style="list-style-type: none"> No location-specific ARARS would be triggered. 	<ul style="list-style-type: none"> No location-specific ARARS would be triggered.
<u>Location-Specific</u>	<ul style="list-style-type: none"> MCLs/MMCLs for CPCs would potentially be met. No monitoring activities would occur to evaluate compliance. 	<ul style="list-style-type: none"> MCLs/MMCLs for CPCs would be met. Long-term groundwater monitoring would be used to evaluate compliance. 	<ul style="list-style-type: none"> MCLs/MMCLs for CPCs would be met. Long-term groundwater monitoring would be used to evaluate compliance. 	<ul style="list-style-type: none"> MCLs/MMCLs for CPCs would be met. Long-term groundwater monitoring would be used to evaluate compliance. 	<ul style="list-style-type: none"> MCLs/MMCLs for CPCs would be met. Long-term groundwater monitoring would be used to evaluate compliance.
<u>Chemical-Specific</u>					

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ASSESSMENT FACTORS	ALTERNATIVE 1: NO ACTION	ALTERNATIVE 2: INTRINSIC BIOREMEDIATION	ALTERNATIVE 3: INTRINSIC BIOREMEDIATION / PASSIVE IN-SITU BIOREMEDIATION CONTAINMENT	ALTERNATIVE 4: INTRINSIC BIOREMEDIATION / HYDRAULIC CONTAINMENT	ALTERNATIVE 5: GROUNDWATER COLLECTION & TREATMENT / SOIL TREATMENT
<u>Action-Specific</u>	<ul style="list-style-type: none">No action or monitoring performed.	<ul style="list-style-type: none">Long-term groundwater monitoring will meet the intent of 310 CMR 30.660-30.679.	<ul style="list-style-type: none">Same as Alternative 2. Also Oxygen Releasing Compound application would be in compliance with 40 CFR Parts 144 & 146 Underground Injection Control Program, and 310 CMR 27.00 Underground Water Source Protection.	<ul style="list-style-type: none">Same as Alternative 2. Also groundwater discharge would meet Pretreatment Program 40 CFR Part 403 requirements; disposal of treatment residues would meet 40 CFR 268; and air emissions would meet 310 CMR 6.00-7.00.	<ul style="list-style-type: none">Same as Alternative 4. Also SVE vapor treatment would meet 310 CMR 7.00 by reducing VOCs by a minimum of 95%.
<u>Long-Term Effectiveness and Permanence</u>					
<u>Adequacy and Reliability of Controls</u>	<ul style="list-style-type: none">Not applicable	<ul style="list-style-type: none">No untreated groundwater that creates human health risk will remain at the site. Five-year site reviews will be performed until PRGs are achieved. Long-term monitoring will continue until 3 consecutive sampling rounds report concentrations below PRGs.	<ul style="list-style-type: none">Same as Alternative 2.	<ul style="list-style-type: none">Same as Alternative 2.	<ul style="list-style-type: none">Same as Alternative 2.

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<u>Magnitude of Residual Risk</u>	<ul style="list-style-type: none"> Can potentially reduce risk by reducing CPCs to PRGs by intrinsic bioremediation. No monitoring activities would occur to evaluate magnitude of residual risk. 	<ul style="list-style-type: none"> CPCs in groundwater are reduced to PRGs by intrinsic bioremediation. 	<ul style="list-style-type: none"> Same as Alternative 2. 	<ul style="list-style-type: none"> Groundwater extraction also permanently removes CPCs from groundwater. The possibility of groundwater re-contamination exists when aquifer rebounds after groundwater extraction is stopped. 	<ul style="list-style-type: none"> Same as Alternative 4. SVE will permanently remove organic CPCs from the soil directly above the groundwater table to minimize probability of groundwater re-contamination. The possibility of groundwater re-contamination may still exist when aquifer rebounds after groundwater extraction is stopped.
<u>Reduction of Toxicity, Mobility, or Volume through Treatment</u>	<ul style="list-style-type: none"> Can potentially reduce toxicity, mobility and volume of CPCs by intrinsic bioremediation. No monitoring activities would occur to evaluate effectiveness. 	<ul style="list-style-type: none"> Intrinsic bioremediation destroys the organic CPCs, reducing toxicity, volume and the possibility that CPCs exceeding PRGs migrate off Army Reserve Enclave property. 	<ul style="list-style-type: none"> Same as Alternative 2. Passive bioremediation wells will promote aerobic biodegradation which can further reduce organic CPC migration potential. 	<ul style="list-style-type: none"> Same as Alternative 2. Groundwater extraction & treatment also reduces toxicity and volume and hydraulically contains the plume. 	<ul style="list-style-type: none"> Same as Alternative 4. SVE also is implemented to extract and treat organic CPCs from the soil that might otherwise re-contaminate the groundwater upon aquifer rebound.
<u>Irreversible Treatment</u>	<ul style="list-style-type: none"> Potentially provides intrinsic bioremediation as detailed in Alternative 2. No monitoring activities would occur to evaluate the treatment. 	<ul style="list-style-type: none"> Organic CPCs permanently destroyed to CO₂, methane and water and reduced to PRGs. Inorganic CPCs are reverted back to more insoluble inorganic forms. 	<ul style="list-style-type: none"> Same as Alternative 2. Passive bioremediation wells will also promote aerobic biodegradation that will permanently degrade contaminants to CO₂ and water. 	<ul style="list-style-type: none"> Same as Alternative 2. Groundwater treatment removes organic CPCs from the site by adsorption on activated carbon. 	<ul style="list-style-type: none"> Same as Alternative 4. Also, effluent gases from the SVE system adsorbed by activated carbon.
<u>Type and Quantity of Residuals Remaining after Treatment</u>	<ul style="list-style-type: none"> None. 	<ul style="list-style-type: none"> None. 	<ul style="list-style-type: none"> None. 	<ul style="list-style-type: none"> Pretreatment wastes (sludge, filtered residue) and spent activated carbon. 	<ul style="list-style-type: none"> Same as Alternative 4 plus spent vapor phase activated carbon from the SVE system.

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ASSESSMENT FACTORS	ALTERNATIVE 1: NO ACTION	ALTERNATIVE 2: INTRINSIC BIOREMEDIATION	ALTERNATIVE 3: INTRINSIC BIOREMEDIATION / PASSIVE IN-SITU BIOREMEDIATION CONTAINMENT	ALTERNATIVE 4: INTRINSIC BIOREMEDIATION / HYDRAULIC CONTAINMENT	ALTERNATIVE 5: GROUNDWATER COLLECTION & TREATMENT / SOIL TREATMENT
<u>Statutory Preference for Treatment</u>	<ul style="list-style-type: none">• Potentially satisfied but treatment can not be verified.	<ul style="list-style-type: none">• Satisfied.	<ul style="list-style-type: none">• Satisfied.	<ul style="list-style-type: none">• Satisfied.	<ul style="list-style-type: none">• Satisfied.
<u>Short-Term Effectiveness</u>					
<u>Community Protection</u>	<ul style="list-style-type: none">• No short-term effects.	<ul style="list-style-type: none">• No short-term effects to the community. Long-term groundwater monitoring will assess the potential of CPCs migrating off Army Reserve Enclave property.	<ul style="list-style-type: none">• Same as Alternative 2.	<ul style="list-style-type: none">• Risk to community minimized through transportation and disposal regulations of groundwater treatment wastes.	<ul style="list-style-type: none">• Same as Alternative 4. Risk to community also minimized through air regulations applicable to SVE effluent air stream.
<u>Worker Protection</u>	<ul style="list-style-type: none">• No work performed.	<ul style="list-style-type: none">• All site activities would require following a HASP.	<ul style="list-style-type: none">• All site activities would require following a HASP.	<ul style="list-style-type: none">• All site activities would require following a HASP.	<ul style="list-style-type: none">• Same as Alternative 4.
<u>Environmental Impacts</u>	<ul style="list-style-type: none">• No work performed.	<ul style="list-style-type: none">• No impacts from groundwater monitoring well installation.	<ul style="list-style-type: none">• No impacts from groundwater monitoring and bioremediation well installations.	<ul style="list-style-type: none">• Dust controls would be utilized during construction activities. Surface water runoff restrictions would be imposed.	<ul style="list-style-type: none">• Same as Alternative 4.

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<u>Time Until Action is Complete</u>	<ul style="list-style-type: none"> No action performed. 	<ul style="list-style-type: none"> Approximately 27 years for CPCs to be reduced below PRGs. Approximately 29 years of long-term groundwater monitoring. 	<ul style="list-style-type: none"> Same as Alternative 2. Passive bioremediation containment minimizes migration potential but does not shorten the time for remedial action. 	<ul style="list-style-type: none"> Approximately 36 years of groundwater pumping and 27 years of intrinsic bioremediation treatment / groundwater treatment. Approximately 29 years of groundwater monitoring plus monitoring during years 36 to 38. 	<ul style="list-style-type: none"> Approximately 27 years for CPCs to be reduced below PRGs and 29 years of long-term groundwater monitoring. SVE would reduce organic CPCs in soil (to target levels that would minimize potential for groundwater re-contamination) within approximately 2 years.
<u>Implementability</u>					
<u>Ability to Construct and Operate</u>	<ul style="list-style-type: none"> No action performed. 	<ul style="list-style-type: none"> Long-term groundwater monitoring program easy to implement. Predesign data and modeling are required to refine degradation rates prior to installing additional wells and implementing long-term monitoring plan. 	<ul style="list-style-type: none"> Same as Alternative 2. In addition, application of Oxygen Releasing Compound will require laboratory treatability tests and if required, minimal field pilot testing to obtain needed design parameters. Required engineering and construction services readily available for installation of bioremediation wells. 	<ul style="list-style-type: none"> Required engineering and construction services readily available for installing a groundwater treatment facility and monitoring wells. Pumping tests and hydrogeologic modeling are required to refine well numbers, position and pumping rates to contain the plume. 	<ul style="list-style-type: none"> Same as Alternative 4. An SVE pilot test would also be required to establish required SVE design parameters.
<u>Ease of Undertaking Additional Action</u>	<ul style="list-style-type: none"> Would not interfere with future actions. 	<ul style="list-style-type: none"> Would not interfere with future actions. 	<ul style="list-style-type: none"> Would not interfere with future actions. 	<ul style="list-style-type: none"> Would not interfere with future actions. 	<ul style="list-style-type: none"> Would not interfere with future actions.
<u>Ability to Monitor Effectiveness</u>	<ul style="list-style-type: none"> No monitoring performed. 	<ul style="list-style-type: none"> Effectiveness would be evaluated by long-term groundwater monitoring. 	<ul style="list-style-type: none"> Effectiveness would be evaluated by long-term groundwater monitoring. 	<ul style="list-style-type: none"> Effectiveness would be evaluated by long-term groundwater monitoring. The potential of soil re-contaminating the groundwater may be difficult to assess with soil sampling due to the heterogeneous soil/contamination medium. 	<ul style="list-style-type: none"> Same as Alternative 4. The potential of soil re-contaminating the groundwater may be difficult to assess with soil sampling because of possible impacts from short-circuiting.

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<u>Ability to Obtain Approvals and Coordinate with Other Agencies</u>	<ul style="list-style-type: none">No additional approvals required.	<ul style="list-style-type: none">Implementation of five-year site reviews would require coordination with the environmental regulators.	<ul style="list-style-type: none">Same as Alternative 2.	<ul style="list-style-type: none">Same as Alternative 2.	<ul style="list-style-type: none">Same as Alternative 2.
<u>Availability of Services and Capacity</u>	<ul style="list-style-type: none">No action performed.	<ul style="list-style-type: none">Sampling and analytical services readily available.Engineering and construction services readily available.	<ul style="list-style-type: none">Same as Alternative 2.	<ul style="list-style-type: none">Same as Alternative 2.	<ul style="list-style-type: none">Same as Alternative 2.
<u>Availability of Equipment Specialists and Materials</u>	<ul style="list-style-type: none">No action performed.	<ul style="list-style-type: none">Groundwater sampling, intrinsic bioremediation modeling and groundwater monitoring well installation experience is available locally.	<ul style="list-style-type: none">Same as Alternative 2. Currently there is only one manufacturer of magnesium peroxide Oxygen Releasing Compound and several manufacturers of calcium peroxide Oxygen Releasing Compound.	<ul style="list-style-type: none">Groundwater extraction and treatment suppliers are available locally.	<ul style="list-style-type: none">Same as Alternative 4. SVE systems can also be installed by local contractors.
<u>Availability of Technologies</u>	<ul style="list-style-type: none">No action performed. Groundwater monitoring is a common technology.	<ul style="list-style-type: none">Groundwater monitoring and well installation are common technologies.	<ul style="list-style-type: none">Same as Alternative 2. The Oxygen Releasing Compound technology is very basic but requires laboratory treatability testing.	<ul style="list-style-type: none">Groundwater extraction and carbon adsorption is a very common remedial technology.	<ul style="list-style-type: none">Same as Alternative 4. SVE is also a commonly applied remedial technology.
Cost					
Capital Cost	\$0	\$47,200	\$134,600	\$270,100	\$388,000
Present Worth O&M Cost	\$0	\$394,500	\$1,003,400	\$1,433,700	\$1,489,900
Present Worth Cost	\$0	\$441,700	\$1,138,000	\$1,703,800	\$1,877,900

Notes:

CO₂ = Carbon dioxide

(continued)

CPC	=	Chemical of Potential Concern
HASP	=	Health and Safety Plan
MADEP	=	Massachusetts Department of Environmental Protection
MCL	=	Maximum Contaminant Level
MMCL	=	Massachusetts Maximum Contaminant Level

LIST OF ACRONYMS AND ABBREVIATIONS

ABB-ES	ABB Environmental Services, Inc.
AOC	Area of Contamination
ARAR	applicable or relevant and appropriate requirement
ATEC	ATEC Associates, Inc.
bgs	below ground surface
BRAC	Base Realignment and Closure Act of 1990
BTEX	benzene, toluene, ethylbenzene, and xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm ²	centimeters squared
cm/sec	centimeters per second
CPC	Chemical of Potential Concern
1,2-DCE	1,2-dichloroethene
EMO	Environmental Management Office
EPC	exposure point concentrations
FFA	Federal Facility Agreement
FS	Feasibility Study
GAC	granular activated carbon
GC	gas chromatograph
GPM	gallons per minute
HI	hazard index
HQ	hazard quotient
IAG	Interagency Agreement
IR	infrared spectrophotometer
MADEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
MCP	Massachusetts Contingency Plan
m/day	meters per day
mg/L	milligrams per liter

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LIST OF ACRONYMS AND ABBREVIATIONS

mgd	million gallons per day
MMCL	Massachusetts Maximum Contaminant Level
MSL	mean sea level
NCP	National Contingency Plan
NDIR	nondispersed infrared spectroscopy
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
O&M	operations and maintenance
ORC	oxygen release compounds
ORP	oxidation reduction potential
PAL	Project Analyte List
PID	photoionization detector
ppm	parts per million
PRE	preliminary risk evaluation
PRG	Preliminary Remediation Goals
PVC	polyvinyl chloride
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision
SA	Study Area
SARA	Superfund Amendments and Reauthorization Act
scfm	standard cubic feet per minute
SCS	Soil Conservation Service
SI	Site Investigation
SMCL	Secondary Maximum Contaminant Levels
SMMCL	Secondary Massachusetts Maximum Contaminant Levels
SSI	Supplemental Site Investigation
SVE	soil vapor extraction
SVOC	semivolatile organic compounds

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LIST OF ACRONYMS AND ABBREVIATIONS

TCLP	toxicity characteristic leaching procedure
TEX	toluene, ethylbenzene, and xylenes
TIC	tentatively identified compounds
TOC	total organic carbon
TPHC	total petroleum hydrocarbons
TSD	treatment, storage, and disposal
TSS	total suspended solids
$\mu\text{g/g}$	micrograms per gram
$\mu\text{g/L}$	micrograms per liter
USAEC	U.S. Army Environmental Center
USEPA	U.S. Environmental Protection Agency
UST	underground storage tank
UV	ultraviolet
VOC	volatile organic compound
w.c.	water column
WWTF	waste water treatment facility

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REFERENCES

- ABB Environmental Services, Inc., 1995. "Revised Final Site Investigation Report, Fort Devens, Groups 2, 7, and Historic Gas Stations". Prepared by ABB-ES for the US Army Toxic and Hazardous Materials Agency (now the USAEC). October 1995.
- ABB Environmental Services, Inc., 1996. "Final Remedial Investigation Report, Fort Devens, Groups 2 and 7 Sites, AOC 43J." Prepared by ABB-ES for the U.S. Army Environmental Center (USAEC). February 1996.
- ATEC Environmental Consultants, 1992a. "Technical Report, Site 8, Underground Storage Tank Closure, UST No. 0055, Building 2446, Fort Devens, Massachusetts"; ATEC File No. 37.07.91.00451; Norwell, MA; prepared for U.S. Army Directorate of Contracting; Fort Devens, Massachusetts; November 5. [SA 43J]
- ATEC Environmental Consultants, 1992b. "Post-Removal Report, Underground Storage Tank Closure, 5,000 Gallon Gasoline, UST No. 0112, Building 2446, Fort Devens, Massachusetts"; ATEC File No. 37.07.91.07541; Norwell, MA; prepared for U.S. Army Directorate of Contracting; Fort Devens, Massachusetts; September 24. [SA 43J]
- ATEC Environmental Consultants, 1993. "Technical Report, Site 14, Underground Storage Tank Closure, UST No. 0112, Building 2446, Fort Devens, Massachusetts"; ATEC File No. 37.07.91.00450; Norwell, MA; prepared for U.S. Army Directorate of Contracting; Fort Devens, Massachusetts; October 29. [SA 43J]
- Base Realignment and Closure Commission Plan (BRAC 91), 1994. PL 101-510 May 1994.
- Beljin, Milovan S., 1990. Groundwater Modeling Software "Solute A Program Package of Analytical Models for Solute Transport in Groundwater"; Holcomb Research Institute, Butler University, Indianapolis, IN 46208.
- Biang, C.A., R.W. Peters, R.H. Pearl, and S.Y. Tsai, 1992. "Master Environmental Plan for Fort Devens, Massachusetts"; prepared for U.S. Army Toxic and Hazardous Materials Agency; prepared by Argonne National Laboratory, Environmental Assessment and Information Sciences Division; Argonne, Illinois; April.
- Borden, Robert C., Gomez, Carlos A., and Becker, Mark T. "Geochemical Indicators of Intrinsic Bioremediation". Ground Water Vol. 33, No. 2, March-April 1995. Pages 180-189.

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REFERENCES

- Koch, Donald, 1995. Transmittal Memo to the Fort Devens Zone II Designation Process Action Team and attached map "Zone II Delineations Based on Manual Tracing of Velocity Vectors 7/28/95"; August 1.
- Lovely, Derek R., F. H. Chapelle, and J. C. Woodward, 1994. "Use of Dissolved H₂ Concentrations to Determine Distribution of Microbially Catalyzed Redox Reactions in Anoxic Groundwater." Environmental Science and Technology; Vol 28, No. 7, July.
- McAllister, P.M. and Chiang, C.Y. "A Practical Approach to Evaluating Natural Attenuation of Contaminants in Ground Water". GWMR Spring 1994. Pages 161-173.
- Rasco Inc., 1991. "Wastewater Discharge Management Plan, Fort Devens, Massachusetts" prepared for Fort Devens and U.S. Army Center for Public Works, Alexandria, Virginia; Contract No. DACA 31-93-D-0061; March.
- Soil Conservation Service, 1991. "Middlesex County Massachusetts Interim Soil Survey Report"; U.S. Department of Agriculture; Middlesex Conservation District; Westford, MA (includes Soil Sheet #19).
- U.S. Environmental Protection Agency, 1988. "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA"; USEPA Office of Emergency and Remedial Response, EPA/540/G-89/004, OSWER Directive 9355.3-01; October.
- U.S. Environmental Protection Agency (USEPA) Region I and the U.S. Department of the Army, 1991a. *In the Matter of: The U.S. Department of the Army, Fort Devens Army Installation, Fort Devens, Massachusetts*. Federal Facility Agreement under the Comprehensive Environmental Response, Compensation, and Liability Act, Section 120. May 13.
- U.S. Environmental Protection Agency (USEPA), 1991b. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. Washington D.C. OSWER Directive 9355.0-30.
- U.S. Environmental Protection Agency (USEPA), 1991c. *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary remediation Goals)*. Publication 9298.7-013. December 1991

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REFERENCES

and Revision October 1992.

U.S. Environmental Protection Agency (USEPA), 1993. "Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites With Volatile Organic Compounds in Soils"; Directive: 9355.0-48FS; September 1993.

Vanasse Hangen Brustlin, Inc., 1994. "Devens Reuse Plan". Prepared for The Boards of Selectmen - Town of Ayer, Town of Harvard, Town of Lancaster, Town of Shirley, and the Massachusetts Government Land Bank; November 14.

Zen, E-an, Edl, 1983. "Bedrock Geologic Map of New England." U.S. Geological Survey; Scale 1:250,000; three sheets.

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Table A-1
Computed Contaminant Concentrations in Groundwater
Based on Detected Soil Concentrations
Feasibility Study Report - AOC 43J
Fort Devens

Analyte	Koc (ml/g)	foc (g/g)	Kd (ml/g)	Maximum Detected Soil Conc. (µg/g) [a]	Average Detected Soil Conc. (µg/g) [a]	Computed Water Conc. Based on Max. Soil Conc. (µg/ml) [b]	Computed Water Conc. Based on Avg. Soil Conc. (µg/ml) [b]	Maximum Detected Water Conc. (µg/ml)	12/94 Max Detected Water Conc. (µg/ml)
ethylbenzene	1100	0.0009	1.045	30	7	29	7	4	3
toluene	300	0.0009	0.285	26	3	91	11	8	7
benzene	83	0.0009	0.07885	0.82	0.1	10	1.1	0.3	0.3
xylene	830	0.0009	0.7885	100	15	127	19	9	8

Notes:

Koc (ml/g) = Soil organic carbon/water partition coefficient

foc (g/g) = Fraction organic carbon in soil

Kd (ml/g) = Soil/water partition coefficient

[a] Where both terraprobe screening results and off-site lab results were obtained for the same location, the off-site lab results were used.

[b] Computed water concentrations = maximum detected soil concentration/Kd

[c] Computed water concentrations = average detected soil concentration/Kd



MEMORANDUM

To: Jake Jacobson/File
From : Rod Pendleton/Rod Rustad
Date: February 6, 1996
Subject: Fort Devens/AOC 43J Groundwater Modeling

This memorandum discusses the approach to groundwater modeling and simulation of groundwater extraction for AOC 43J at Fort Devens, MA, and summarizes the findings. Results from the modeling effort are to be used in the selection of remedial alternatives. The objectives of the groundwater modeling are to simulate a groundwater extraction system that a) halts the further migration of contaminants, and b) lowers the groundwater table to allow enhanced soil venting. The QuickFlow model by Geraghty and Miller (v. 1.0, © 1991) was used to simulate the groundwater extraction systems.

ASSUMPTIONS

The following assumptions are inherent in the QuickFlow model:

- 1) QuickFlow is designed to solve two-dimensional groundwater flow problems in a horizontal plane.
- 2) Groundwater flow is horizontal and occurs in an infinite aquifer.
- 3) The aquifer hydraulic conductivity is assumed to be isotropic and homogeneous.
- 4) The reference head in the steady-state model is constant throughout all calculations.
- 5) All pumping rates are constant throughout time.
- 6) All trenches/wells are assumed to fully penetrate the aquifer.

All model runs for this task were performed using the steady-state mode.

Based on these assumptions, it is obvious that the model cannot take into account all site-specific conditions. For example, the model cannot account for the heterogeneities of the fill/till aquifer, or the bedrock aquifer. In addition, simplifying assumptions had to be made regarding groundwater flow direction, gradient, and aquifer thickness since these are not uniform across the site. Therefore, results of this model should not be used for detailed remedial design purposes, but are sufficient to use for the screening of remedial alternatives. For actual remedial design, a more detailed modeling effort is recommended.

MODEL INPUTS

The following inputs were used in the QuickFlow model to simulate conditions at AOC 43J:

Hydraulic Conductivity:	0.86 ft/day (or 3.03e-04 cm/sec)
Effective Porosity:	0.25
Elevation of Top of Aquifer:	380 ft. MSL
Elevation of Bottom of Aquifer:	315 ft. MSL
Uniform Regional Gradient:	0.018 ft/foot

The hydraulic conductivity used is greater than the geometric mean of slug test values from all wells at AOC 43J (see Table 1), is more representative of the plume area where extraction wells and/or trenches are simulated. The saturated till thickness at the site varies from 0 to 10 feet across the modeled area. In order to simulate unconfined conditions at AOC 43J, it was necessary to input an aquifer thickness of 65 feet (380 ft - 315 ft). Resultant saturated aquifer thickness as simulated by the model range between 43 and 50 feet across the site. The equation for the volumetric flow rate, $Q=KiA$, shows that for constant hydraulic conductivity (K) and horizontal hydraulic gradient (I), the volumetric flow rate (Q) is directly proportional to the cross sectional area of saturated aquifer (A). Therefore, modeled extraction rates (Q) are conservative estimates because the saturated thickness simulated by the model is over four times greater than actual site conditions. The uniform regional gradient and groundwater flow direction used in the model are an average approximation of two sets of water level data from the site: January 31, 1995 and May 9, 1995. Water level contour plans for these two dates are presented in the Final RI Report for AOC 43J (February 1996).

Figure 1 presents the simulated static water level at AOC 43J. The reference head (denoted by ® in the upper left corner of Figure 1) remains constant throughout the steady-state simulation, providing water to the model. As a result, recharge was not input into the model (see Section 6, Model Verification, in the QuickFlow Version 1.0 manual, September 1991 for a comparison of QuickFlow vs. MODFLOW).

MODEL RUNS AND RESULTS

Model simulations were performed for both trench and vertical extraction well scenarios. Note that the interpreted 5 ug/L benzene contour is present on Figure 1 through 6 inside the fenced boundary of AOC 43J.

Trench Scenario

The trench extraction simulation consists of one trench approximately 160 feet in length, with groundwater collection at a rate of 2 gallons per minute (gpm) (see Figure 2). This scenario provides for effective hydraulic containment of the groundwater contaminant plume as well as lowering the water table 2 feet in the vicinity of the source area. As discussed above the simulated 2 gpm extraction rate is a conservative estimate. Known saturated aquifer thickness would require an extraction rate of approximately 0.5 gpm.

As a check of the models viability the volumetric flow rate, the amount of water flowing through a given area over a given time, was calculated for the saturated cross-sectional area of the extraction trench under static conditions (no pumping):

$$\begin{aligned}Q &= KiA \\K &= 0.86 \text{ ft/day} \\i &= 0.018 \text{ ft/ft} \\ \text{length of trench} &= 160 \text{ ft} \\ \text{saturated thickness} &= 45 \text{ ft (model), 10 ft (actual conditions)}\end{aligned}$$

$$Q_{\text{model}} = 0.6 \text{ gpm}$$

$$Q_{\text{actual}} = 0.13 \text{ gpm}$$

These calculated volumetric flow rates indicate that the modeled estimates are viable.

Vertical Extraction Well Scenarios

The vertical extraction well scenario consists of three 6-inch inside diameter extraction wells with a cumulative pumping rate of 1.5 gpm (see Figure 3). This scenario provides hydraulic containment of the groundwater contaminant plume, and lowers the groundwater levels in the source area on the order of 2 foot. As discussed above, the extraction rate of 1.5 gpm is a conservative estimate.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the model simulations, it appears that hydraulic containment of the groundwater plume can be obtained with a total pumping rate of approximately 0.4 to 0.5 gallons per minute. Both the trench and vertical extraction wells lower the water table by 2 feet in the vicinity of the contaminant source area.

To repeat, results of the QuickFlow model runs are not recommended for detailed remedial design purposes, but are sufficient to use for the screening of remedial alternatives. For actual remedial design, a more detailed modeling effort is recommended.

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WELL	TEST TYPE	Hydraulic Conductivities	
		Bouwer & Rice (cm/sec)	Hvorslev (cm/sec)
XJM-94-05X	RISING HEAD	9.6E-07	8.5E-06
XJM-94-07X	RISING HEAD	8.4E-04	5.6E-04
XJM-94-08X	RISING HEAD	1.6E-03	1.7E-03
XJM-94-09X	FALLING HEAD	1.9E-04	3.9E-05
XJM-94-09X	RISING HEAD	2.1E-04	7.2E-05
XJM-94-10X	FALLING HEAD	4.4E-04	1.0E-06
2446-02	RISING HEAD	3.4E-05	9.5E-06
2446-03	RISING HEAD	9.6E-05	2.1E-05
2446-04	FALLING HEAD	3.3E-05	7.6E-06
2446-04	RISING HEAD	2.8E-05	6.8E-06
XJP-94-01X	RISING HEAD	4.0E-04	3.7E-04
XJP-94-02X	FALLING HEAD	6.6E-05	1.6E-05
XJP-94-02X	RISING HEAD	2.9E-03	3.3E-04

	Geom. Mean of Ks (cm/sec)	GW Velocity (m/day)
All Wells	7.3E-05	5.5E-03
XJP-94-02X and XJM-94-08X	3.7E-04	2.8E-02
2446-02, XJM-94-05X, XJP-94-01X, XJP-94-02X, and XJM-94-08X	1.0E-04	7.6E-03

Note: For computing GW Velocity, $i=0.022$ and $n=0.25$.

Last Revised:

6-Feb-96

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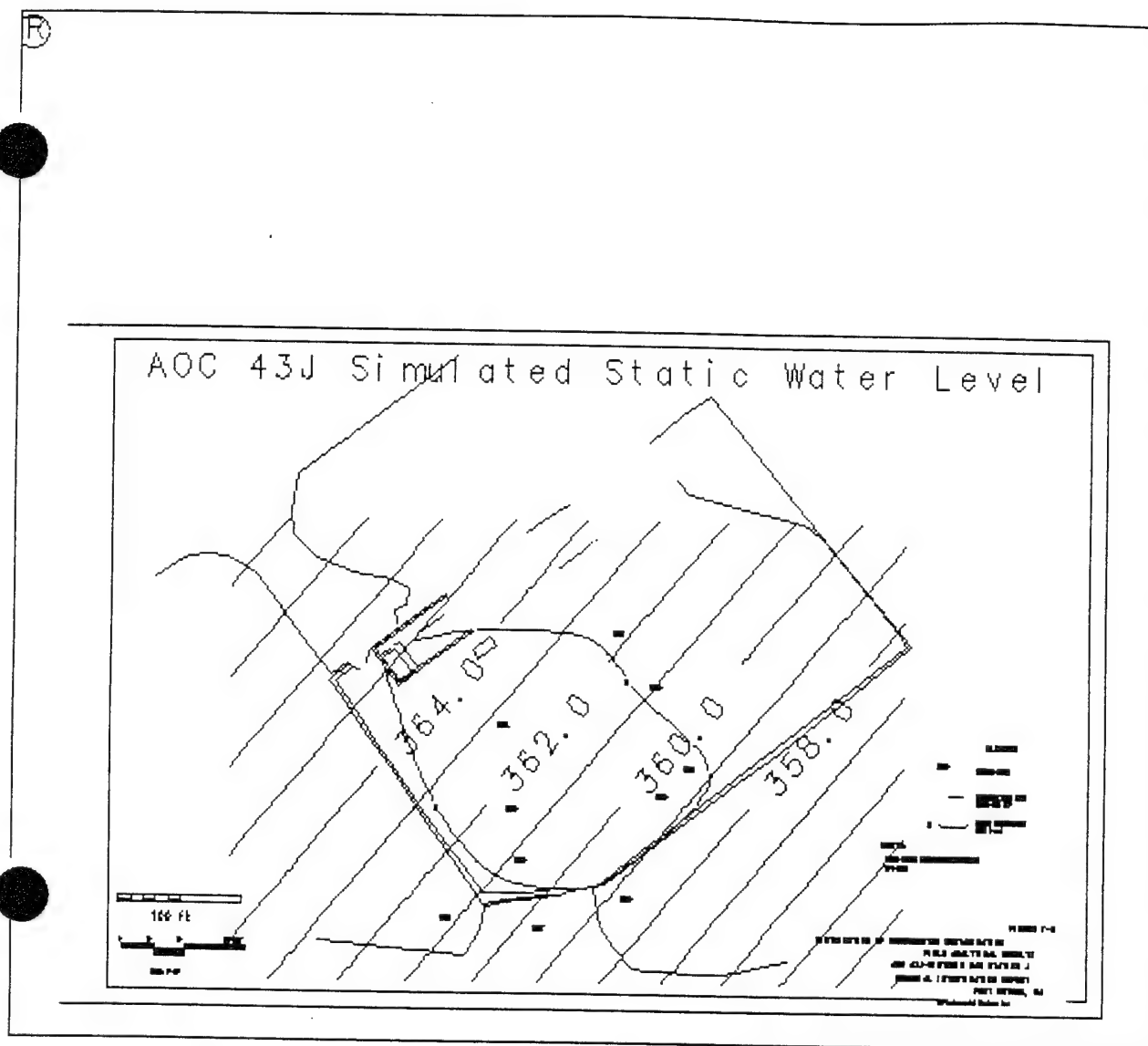


FIGURE 1

AOC 43J SIMULATED STATIC WATER LEVEL

®

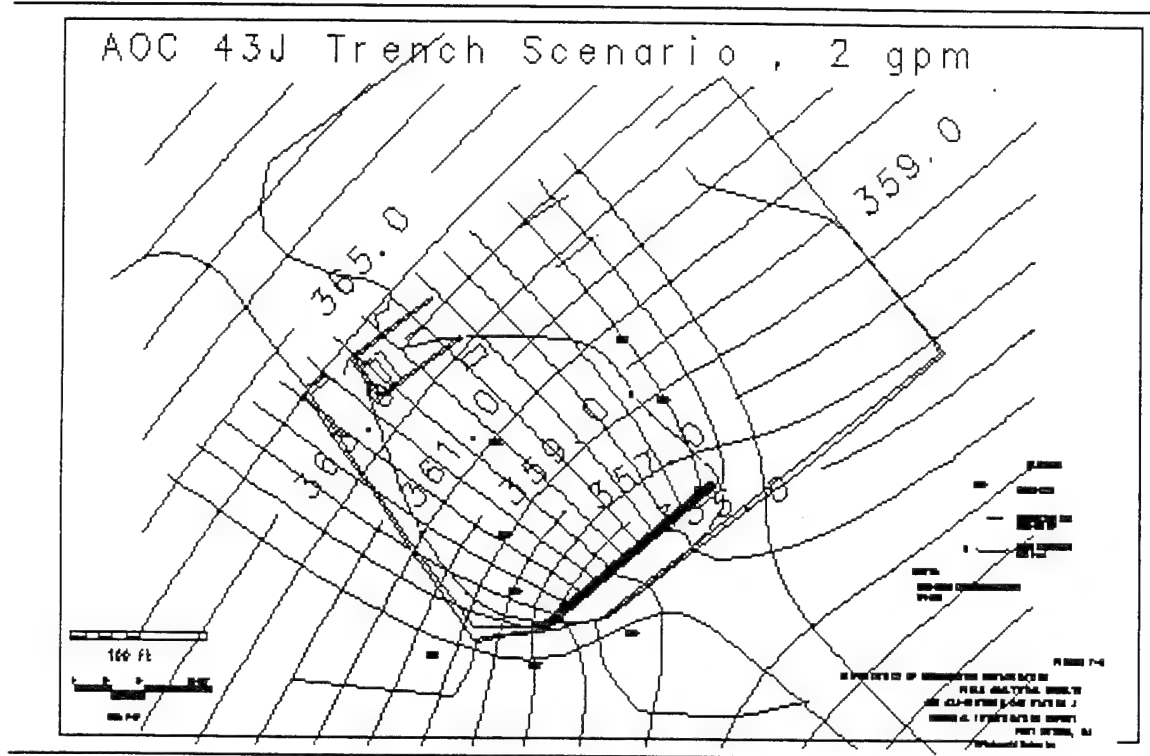


FIGURE 2

AOC 43J EXTRACTION TRENCH SCENARIO

TOTAL Q = 2 GPM

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QuickFlow
Analytical Model of 2D Ground-Water Flow

Developed by
James O. Rumbaugh, III

(c) 1991 Geraghty & Miller, Inc.

=====

Date: 2/5/1996
Time: 11:38:29.19

Input File: 43jw02.qfl
Map File : aoc43j.map

=====

Model Entities

Number of Linesinks Defined by Infiltration Rate = 0

Number of Linesinks Defined by Head = 0

Number of Ponds = 0

Number of Wells = 3

Well #1

Center of Well -- x: 567219.000000 y: 557468.812500

```

Radius = 0.200000
Pumping Rate = 96.000000
Head at Well Radius      = 357.944672
Well #2
Center of Well --  x: 567296.375000  y: 557438.625000
Radius = 0.200000
Pumping Rate = 96.000000
Head at Well Radius      = 355.830723
Well #3
Center of Well --  x: 567247.312500  y: 557412.125000
Radius = 0.200000
Pumping Rate = 96.000000
Head at Well Radius      = 356.257932

```

```

Reference Head = 376.000000   Defined at -- x: 566833.625000   y:
558026.000000

```

```

=====
=====

```

Aquifer Properties

.... Steady-State Flow Model

```

Permeability.....= 0.860000 [L/T]
Porosity.....= 0.250000
Elevation of Aquifer Top....= 380.000000
Elevation of Aquifer Bottom.= 315.000000
Uniform Regional Gradient...= 0.018000
Angle of Uniform Gradient...= 320.000000
Recharge.....= 0.000000

```

```

=====
=====

```

Contour Matrix

```

Number of nodes in the X-direction = 35
Number of nodes in the Y-direction = 35

```

```

Minimum X Coordinate = 566977.187500

```

Minimum Y Coordinate = 557257.187500

Maximum X Coordinate = 567594.875000

Maximum Y Coordinate = 557737.000000

Minimum Head = 350.894958

Maximum Head = 369.865112

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=====

QuickFlow
Analytical Model of 2D Ground-Water Flow

Developed by

James O. Rumbaugh, III

(c) 1991 Geraghty & Miller, Inc.

=====

Date: 2/5/1996
Time: 9:45:29.57

Input File: 43jstat2.qfl
Map File : aoc43j.map

=====

Model Entities

Number of Linesinks Defined by Infiltration Rate = 0

Number of Linesinks Defined by Head = 0

Number of Ponds = 0

Number of Wells = 0

Reference Head = 376.000000 Defined at -- x: 566833.625000 y:
558026.000000

=====

Aquifer Properties

.... Steady-State Flow Model

Permeability.....= 0.860000 [L/T]
Porosity.....= 0.250000
Elevation of Aquifer Top....= 380.000000
Elevation of Aquifer Bottom.= 315.000000
Uniform Regional Gradient...= 0.018000
Angle of Uniform Gradient...= 320.000000
Recharge.....= 0.000000

=====

Contour Matrix

Number of nodes in the X-direction = 35
Number of nodes in the Y-direction = 35

Minimum X Coordinate = 566999.875000
Minimum Y Coordinate = 557259.125000

Maximum X Coordinate = 567551.375000
Maximum Y Coordinate = 557635.000000

Minimum Head = 352.829620
Maximum Head = 368.753174

12:35PM 2/5/96

=====

QuickFlow
Analytical Model of 2D Ground-Water Flow

Developed by

James O. Rumbaugh, III

(c) 1991 Geraghty & Miller, Inc.

=====

Date: 2/5/1996
Time: 10:59:15.47

Input File: 43jt02.qfl
Map File : aoc43j.map

=====

Model Entities

Number of Linesinks Defined by Infiltration Rate = 1

Line Sink #1

x1: 567256.812500 y1: 557330.875000
x2: 567385.187500 y2: 557436.687500
Discharge per length = 2.400000
Head in Center of Linesink = 353.870213
Total Linesink Discharge = 399.269615 [L3/T]

Number of Linesinks Defined by Head = 0

Number of Ponds = 0

Number of Wells = 0

Reference Head = 376.000000 Defined at -- x: 566833.625000 y:
558026.000000

=====

Aquifer Properties

.... Steady-State Flow Model

Permeability.....= 0.860000 [L/T]
Porosity.....= 0.250000
Elevation of Aquifer Top....= 380.000000
Elevation of Aquifer Bottom.= 315.000000
Uniform Regional Gradient...= 0.018000
Angle of Uniform Gradient...= 320.000000
Recharge.....= 0.000000

=====

Contour Matrix

Number of nodes in the X-direction = 35
Number of nodes in the Y-direction = 35

Minimum X Coordinate = 566962.125000
Minimum Y Coordinate = 557245.875000

Maximum X Coordinate = 567621.312500
Maximum Y Coordinate = 557729.375000

Minimum Head = 349.112305
Maximum Head = 369.912720



MEMORANDUM

To: Jake Jacobson/File
From : Rod Pendleton
Date: February 6, 1996
Subject: Fort Devens/AOC 43J Solute Transport Modeling

This memorandum discusses the approach to solute transport modeling for AOC 43J at Fort Devens, MA, and summarizes the findings. Data from the modeling effort is to be used in the assessment of potential remedial alternatives for AOC 43J. The objective of the solute transport modeling is to simulate existing and future concentrations of contaminants of concern detected in groundwater at the site. In particular, the model assists in estimating contaminant concentrations over time along a flowpath from the source area at the site to the enclave boundary, 110 to 120 meters downgradient.

The ONED3 analytical model for solute transport from the International Groundwater Modeling Center Solute Program Package (Beljin, 1990) was used to simulate solute transport of the following contaminants of concern: benzene, toluene, ethylbenzene, and carbon tetrachloride.

MODEL ASSUMPTIONS

The following assumptions are inherent in the ONED3 model:

- 1) the aquifer is assumed to be uniformly porous and confined;
- 2) the aquifer is homogeneous, isotropic, semi-infinite in the areal extent, and of constant thickness;
- 3) a (contaminant) source/stream fully penetrates the aquifer;
- 4) there is one-dimensional steady-state uniform regional groundwater flow from the source/stream;
- 5) the density and viscosity of the solute in the source area and aquifer are the same; and
- 6) no solute advection or dispersion occurs through the aquicludes into or out of the aquifer.

This model was selected to provide a conservative estimate of solute transport at AOC 43J (i.e., to provide solute transport estimates that are likely to exceed actual concentrations and transport distances). The model conservatively does not account for dilution due to lateral and vertical dispersion.

Based on the assumptions listed above, it is obvious that the model cannot take into account all site-specific conditions. For example, the model cannot account for the heterogeneities of the aquifer. In addition, simplifying assumptions had to be made regarding groundwater flow direction and gradient, since these are not uniform across the site.

MODEL INPUTS

The following inputs were used in the ONED3 model to simulate conditions at AOC 43J:

Groundwater Velocity:	0.01 m/day
Longitudinal Dispersivity:	12 m

Supporting calculations for these parameters are attached. The groundwater velocity used is slightly higher than that calculated using the geometric mean of hydraulic conductivity values from all monitoring wells and piezometers. Therefore, the velocity is conservatively high with regard to contaminant dispersion/transport. Groundwater flow direction at the site is assumed to be to the southeast (see Figure 1), generally along the centerline of the groundwater contaminant plumes. The regional gradient and flow direction are averages based on approximation of two sets of water level data from the site: January 31, 1995 and May 9, 1995. Water level contour plans for these two dates are presented in the AOC 43J Final RI Report (February 1996). Calculations of retardation factors for individual contaminants of concern are also attached.

A literature search on decay rates/half-lives of the contaminants of concern was performed, and is summarized in an attachment. Initial decay rates used for modeling contaminants of concern were within the range determined from the literature search for each compound, and were typically conservative in allowing for less decay than the average values reported.

For modeling purposes, the source area was assumed to be located between the gasoline and waste oil UST excavations, to the southwest of Building T2446 (see Figure 1). In all model simulations, the source was turned "on" from the years 1960 to 1992 (11,680 days total), to simulate the leaking USTs; the leaking USTs were removed in 1992.

Model simulations were made for the following contaminants of concern: benzene, toluene, ethylbenzene, and carbon tetrachloride.

MODEL CALIBRATION

The model simulations for each contaminant of concern were performed using the same values for groundwater velocity (0.01 m/day) and longitudinal dispersivity (12 m). Contaminant-specific retardation factors were applied to each simulation. Target concentrations for model calibration were estimated from Figure 2, which presents the estimated distribution of organic groundwater contamination above MCLs in March, 1995. Target concentrations relative to distance from the source area are presented with the output files of the model simulations (attached).

The input parameter for which there is no data available is the concentration at the source. A trial and error approach was taken to estimate the source concentration. Decay rates/half-lives of the contaminants of concern were adjusted in conjunction with the source concentration to obtain a "best-fit" with the 1995 calibration targets. The objective with respect to calibration was to match the center and downgradient edges of the plume as closely as possible with the 1995 calibration targets. Calibration was considered satisfactory when model simulation concentrations (1995) reasonably approximated the 1995 calibration target concentrations. The simplified representation of the source/leak, which is likely to have been variable over the years, defies exact model calibration.

MODEL SIMULATION RESULTS

The outputs of the final model simulations for each of the contaminants of concern are attached. Discussions of the contaminant-specific simulation results are presented below.

Benzene

The simulated 1995 concentration of 0.0077 mg/L at the leading edge of the benzene plume (60 meters) is slightly above the calibration target of 0.005 mg/L (see attachment). In addition, the simulated concentration in the center of the plume (0.2457 mg/L at 20 meters) reasonably approximates the calibration target of 0.300 mg/L. The simulation indicates that concentrations of benzene would not exceed the MCL of 0.005 mg/L at the enclave boundary (110 to 120 meters from the source area) in the future.

Toluene

The simulated 1995 concentration of 0.0008 mg/L at the leading edge of the toluene plume (70 meters) is slightly above the calibration target of <0.0005 mg/L (see attachment). In addition, the simulated concentration in the center of the plume (2.13 mg/L at 10 meters) reasonably approximates the calibration target of 2.0 mg/L. The simulation indicates that concentrations of toluene would not exceed the MCL of 1.000 mg/L at the enclave boundary (110 to 120 meters from the source area) in the future.

Ethylbenzene

The simulated 1995 concentration of 0.0018 mg/L at the leading edge of the ethylbenzene plume (40 meters) is slightly above the calibration target of <0.0005 mg/L (see attachment). In addition, the simulated concentration of 6.96 mg/L in the center of the plume (20 meters) reasonably approximates the calibration target of 2.0 mg/L. The simulation indicates that concentrations of ethylbenzene would not exceed the MCL of 0.700 mg/L at the enclave boundary (110 to 120 meters from the source area) in the future.

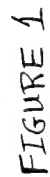
Carbon Tetrachloride

The simulated 1995 concentration of 0.0042 mg/L at the downgradient edge of the carbon tetrachloride plume (40 meters) is slightly below the calibration target of 0.0050 mg/L (see attachment). In addition, the simulated concentration of 0.2777 mg/L in the center of the plume (20 meters) reasonably approximates the calibration target of 0.1000 mg/L. The simulation indicates that concentrations of carbon tetrachloride would not exceed the MCL of 0.005 mg/L at the enclave boundary (110 to 120 meters from the source area) in the future.

SUMMARY AND CONCLUSIONS

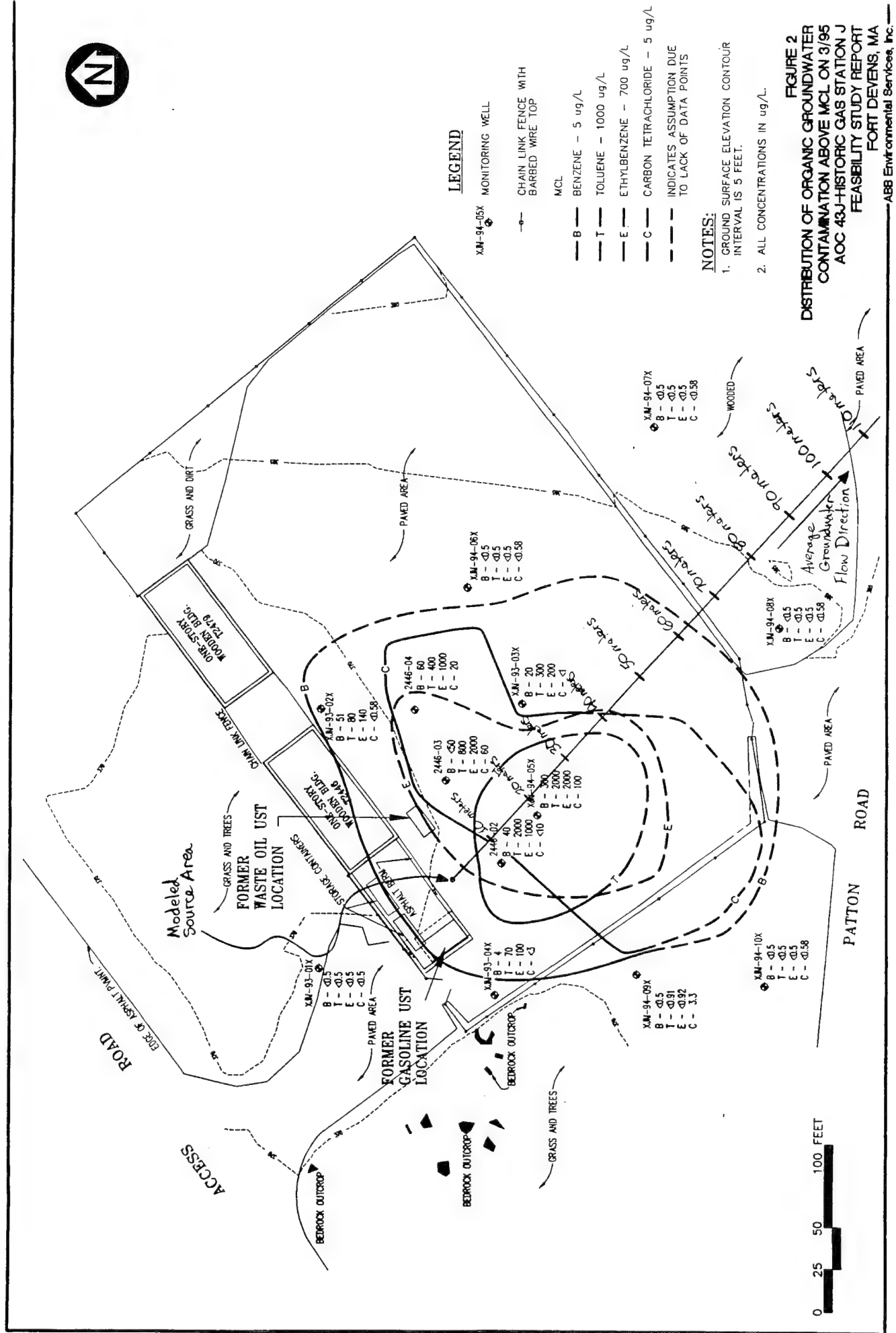
Model simulation results indicate that concentrations of contaminants of concern will not exceed MCLs at the enclave boundary. Inputs used for the model simulations are generally conservative, resulting in potential overestimation of contaminant transport. Review of the model outputs indicates that the retardation factor used in the model simulations allows the time for degradation of the contaminants, as downgradient migration is inhibited. Note that the model cannot account for changes in variables such as aquifer heterogeneities, or spatial and temporal changes in biodegradation rates as a result of contaminant concentration distribution, temperature variations, or bacterial count and type.

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AOC 43J - HISTORIC GAS STATION
FEASIBILITY STUDY PHASE
EPCOT TOWN, MA

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Benzene

Input Parameters:

GROUNDWATER (SEEPAGE) VELOCITY = .01 [m/d]
LONGITUDINAL DISPERSIVITY..... = 12 [m]
RETARDATION FACTOR..... = 1.63
INITIAL CONCENTRATION..... = 0 [mg/l]
CONCENTRATION AT SOURCE..... = 11 [mg/l]
DISTANCE INCREMENT..... = 10 [m]
NUMBER OF DISTANCE INCREMENTS. = 10
NUMBER OF TIME PERIODS..... = 5
1 TIME..... = 5475 [d]
2 TIME..... = 11680 [d]
3 TIME..... = 12775 [d]
4 TIME..... = 14600 [d]
5 TIME..... = 18250 [d]
HALF-LIFE (0 if no decay)..... = 460 [d]
DECAY CONSTANT (lambda)..... = .151D-02 [1/d]
HALF-LIFE at source..... = 0 [d]
DECAY CONSTANT (alpha)..... = .000D+00 [1/d]
DURATION OF SOLUTE PULSE..... = 11680 [d]

Output:

DISTANCE [m]	1975 5475[days]	1992 11680[days]	1995 12775[days]	2000 14600[days]	2005 16425[days]	1995 Calibration Targets
0	4.8074	4.8074	0.1764	0.0045	0.0002	
10	1.6433	1.6433	0.2782	0.0083	0.0003	0.0400
20	0.5616	0.5617	0.2457	0.0110	0.0004	0.3000
30	0.1919	0.1920	0.1413	0.0113	0.0005	
40	0.0655	0.0656	0.0605	0.0093	0.0006	
50	0.0223	0.0224	0.0221	0.0062	0.0005	
60	0.0075	0.0077	0.0077	0.0035	0.0004	0.0050
70	0.0025	0.0026	0.0026	0.0017	0.0003	<0.0005
80	0.0008	0.0009	0.0009	0.0007	0.0002	
90	0.0003	0.0003	0.0003	0.0003	0.0001	
100	0.0001	0.0001	0.0001	0.0001	0.0000	

- Notes: 1) All concentrations are in mg/L (ppm).
2) Distance is the distance from the former source areas (waste oil and gasoline USTs).
3) The modeled source was turned "on" from 1960 to 1992 (date of UST removal) in the simulation.
4) Monitoring well XJM-94-08X is approximately 70 meters downgradient from the source area; the enclave boundary is approximately 120 meters downgradient from the source area.
5) Benzene MCL is 0.005 mg/L.
6) Shading indicates modeled concentrations exceeding the MCL
7) The 1995 calibration targets were derived from the estimated distribution of organic groundwater contamination in March 1995 (see Figure 2).

Toluene

Input Parameters:

GROUNDWATER (SEEPAGE) VELOCITY = .01 [m/d]
LONGITUDINAL DISPERSIVITY..... = 12 [m]
RETARDATION FACTOR..... = 3.29
INITIAL CONCENTRATION..... = 0 [mg/l]
CONCENTRATION AT SOURCE..... = 75 [mg/l]
DISTANCE INCREMENT..... = 10 [m]
NUMBER OF DISTANCE INCREMENTS. = 10
NUMBER OF TIME PERIODS..... = 5
1 TIME..... = 5475 [d]
2 TIME..... = 11680 [d]
3 TIME..... = 12775 [d]
4 TIME..... = 14600 [d]
5 TIME..... = 16425 [d]
HALF-LIFE (0 if no decay)..... = 550 [d]
DECAY CONSTANT (lambda)..... = .126D-02 [1/d]
HALF-LIFE at source..... = 0 [d]
DECAY CONSTANT (alpha)..... = .000D+00 [1/d]
DURATION OF SOLUTE PULSE..... = 11680 [d]

Output:

DISTANCE [m]	1975 5475[days]	1992 11680[days]	1995 12775[days]	2000 14600[days]	2005 16425[days]	1995 Calibration Targets
0	26.9191	26.9209	1.7093	0.0839	0.0052	
10	6.0744	6.0776	2.1304	0.1375	0.0093	2.0000
20	1.3680	1.3721	1.0523	0.1330	0.0112	2.0000
30	0.3058	0.3098	0.2995	0.0842	0.0099	1.4000
40	0.0670	0.0699	0.0698	0.0372	0.0067	0.9000
50	0.0140	0.0158	0.0158	0.0123	0.0035	
60	0.0027	0.0036	0.0036	0.0033	0.0015	
70	0.0005	0.0008	0.0008	0.0008	0.0005	
80	0.0001	0.0002	0.0002	0.0002	0.0001	
90	0.0000	0.0000	0.0000	0.0000	0.0000	
100	0.0000	0.0000	0.0000	0.0000	0.0000	

- Notes:** 1) All concentrations are in mg/L (ppm).
2) Distance is the distance from the former source areas (waste oil and gasoline USTs).
3) The modeled source was turned "on" from 1960 to 1992 (date of UST removal) in the simulation.
4) Monitoring well XJM-94-08X is approximately 70 meters downgradient from the source area; the enclave boundary is approximately 120 meters downgradient from the source area.
5) Toluene MCL is 1.000 mg/L.
6) Shading indicates modeled concentrations exceeding the MCL
7) The 1995 calibration targets were derived from the estimated distribution of organic groundwater contamination in March 1995 (see Figure 2).

Ethylbenzene

Input Parameters:

GROUNDWATER (SEEPAGE) VELOCITY = .01 [m/d]
LONGITUDINAL DISPERSIVITY..... = 12 [m]
RETARDATION FACTOR..... = 9.39
INITIAL CONCENTRATION..... = 0 [mg/l]
CONCENTRATION AT SOURCE..... = 55 [mg/l]
DISTANCE INCREMENT..... = 10 [m]
NUMBER OF DISTANCE INCREMENTS = 10
NUMBER OF TIME PERIODS..... = 5
1 TIME..... = 5475 [d]
2 TIME..... = 11680 [d]
3 TIME..... = 12775 [d]
4 TIME..... = 18250 [d]
5 TIME..... = 23725 [d]
HALF-LIFE (0 if no decay)..... = 3400 [d]
DECAY CONSTANT (lambda)..... = .204D-03 [1/d]
HALF-LIFE at source..... = 0 [d]
DECAY CONSTANT (alpha)..... = .000D+00 [1/d]
DURATION OF SOLUTE PULSE..... = 11680 [d]

Output:

DISTANCE [m]	1975 5475[days]	1992 11680[days]	1995 12775[days]	2010 18250[days]	2025 23725[days]	1995 Calibration Targets
0	24.2607	25.9385	10.2792	1.3435	0.2608	
10	7.4607	9.9928	9.4913	2.1479	0.4618	2.0000
20	1.6095	3.5877	3.7356	1.9645	0.5497	2.0000
30	0.2137	1.1377	1.2485	1.1802	0.4794	
40	0.0161	0.3021	0.3600	0.5177	0.3196	0.7000
50	0.0007	0.0643	0.0859	0.1823	0.1685	
60	0.0000	0.0106	0.0164	0.0545	0.0726	
70	0.0000	0.0013	0.0025	0.0141	0.0263	<0.0005
80	0.0000	0.0001	0.0003	0.0031	0.0082	
90	0.0000	0.0000	0.0000	0.0006	0.0023	
100	0.0000	0.0000	0.0000	0.0001	0.0005	

- Notes:
- 1) All concentrations are in mg/L (ppm).
 - 2) Distance is the distance from the former source areas (waste oil and gasoline USTs).
 - 3) The modeled source was turned "on" from 1960 to 1992 (date of UST removal) in the simulation.
 - 4) Monitoring well XJM-94-08X is approximately 70 meters downgradient from the source area; the enclave boundary is approximately 120 meters downgradient from the source area.
 - 5) Ethylbenzene MCL is 0.700 mg/L.
 - 6) Shading indicates modeled concentrations exceeding the MCL.
 - 7) The 1995 calibration targets were derived from the estimated distribution of organic groundwater contamination in March 1995 (see Figure 2).

Carbon Tetrachloride

Input Parameters:

GROUNDWATER (SEEPAGE) VELOCITY = .01 [m/d]
LONGITUDINAL DISPERSIVITY..... = 12 [m]
RETARDATION FACTOR..... = 4.35
INITIAL CONCENTRATION..... = 0 [mg/l]
CONCENTRATION AT SOURCE..... = 120 [mg/l]
DISTANCE INCREMENT..... = 10 [m]
NUMBER OF DISTANCE INCREMENTS. = 10
NUMBER OF TIME PERIODS..... = 5
1 TIME..... = 5475 [d]
2 TIME..... = 11680 [d]
3 TIME..... = 12775 [d]
4 TIME..... = 14600 [d]
5 TIME..... = 16425 [d]
HALF-LIFE (0 if no decay)..... = 365 [d]
DECAY CONSTANT (lambda)..... = .190D-02 [1/d]
HALF-LIFE at source..... = 0 [d]
DECAY CONSTANT (alpha)..... = .000D+00 [1/d]
DURATION OF SOLUTE PULSE..... = 11680 [d]

Output:

DISTANCE [m]	1975 5475[days]	1992 11680[days]	1995 12775[days]	2000 14600[days]	2005 16425[days]	1995 Calibration Targets
0	32.5384	32.5385	0.9380	0.0147	0.0003	
10	3.4641	3.4642	0.9569	0.0221	0.0005	0.0600
20	0.3687	0.3688	0.2777	0.0168	0.0005	0.1000
30	0.0392	0.0393	0.0383	0.0072	0.0004	
40	0.0041	0.0042	0.0042	0.0019	0.0002	0.0050
50	0.0004	0.0004	0.0004	0.0003	0.0001	
60	0.0000	0.0000	0.0000	0.0000	0.0000	
70	0.0000	0.0000	0.0000	0.0000	0.0000	
80	0.0000	0.0000	0.0000	0.0000	0.0000	<0.00058
90	0.0000	0.0000	0.0000	0.0000	0.0000	
100	0.0000	0.0000	0.0000	0.0000	0.0000	

- Notes:** 1) All concentrations are in mg/L (ppm).
2) Distance is the distance from the former source areas (waste oil and gasoline USTs).
3) The modeled source was turned "on" from 1960 to 1992 (date of UST removal) in the simulation.
4) Monitoring well XJM-94-08X is approximately 70 meters downgradient from the source area; the enclave boundary is approximately 120 meters downgradient from the source area.
5) Carbon Tetrachloride MCL is 0.005 mg/L.
6) Shading indicates modeled concentrations exceeding the MCL.
7) The 1995 calibration targets were derived from the estimated distribution of organic groundwater contamination in March 1995 (see Figure 2).

WELL	TEST TYPE	Hydraulic Conductivities	
		Bouwer&Rice (cm/sec)	Hvorslev (cm/sec)
XJM-94-05X	RISING HEAD	9.6E-07	8.5E-06
XJM-94-07X	RISING HEAD	8.4E-04	5.6E-04
XJM-94-08X	RISING HEAD	1.6E-03	1.7E-03
XJM-94-09X	FALLING HEAD	1.9E-04	3.9E-05
XJM-94-09X	RISING HEAD	2.1E-04	7.2E-05
XJM-94-10X	FALLING HEAD	4.4E-04	1.0E-06
2446-02	RISING HEAD	3.4E-05	9.5E-06
2446-03	RISING HEAD	9.6E-05	2.1E-05
2446-04	FALLING HEAD	3.3E-05	7.6E-06
2446-04	RISING HEAD	2.8E-05	6.8E-06
XJP-94-01X	RISING HEAD	4.0E-04	3.7E-04
XJP-94-02X	FALLING HEAD	6.6E-05	1.6E-05
XJP-94-02X	RISING HEAD	2.9E-03	3.3E-04

	Geom. Mean of Ks (cm/sec)	GW Velocity (m/day)
All Wells	7.3E-05	5.5E-03
XJP-94-02X and XJM-94-08X	3.7E-04	2.8E-02
2446-02, XJM-94-05X, XJP-94-01X, XJP-94-02X, and XJM-94-08X	1.0E-04	7.6E-03

Note: For computing GW Velocity, $i=0.022$ and $n=0.25$.

Last Revised:

15-Jan-96

**Fort Devens - AOC 43J Feasibility Study
Solute Transport Modeling**

Dispersivity Calculations

Longitudinal Dispersivity (α_L) = $0.1x_r$

where x_r = distance to the receptor well (Gelhar and Axness, 1981)

To be conservative (allowing for maximum contaminant dispersion), assume x_r = distance from the source area to the enclave boundary along Patton Road (coincident with the estimated groundwater flow path).

Therefore,

x_r = 120 meters

and

Longitudinal Dispersivity (α_L) = 12.0 meters

Fort Devens Feasibility Study
Solute Transport Modeling
AOC 43J

Calculation of Fraction of Organic Carbon in Soils

<u>Boring</u>	<u>Sample Depth (ft)</u>	<u>TOC (ug/g)</u>	<u>foc</u>
XJM-93-02X	5	1050	0.00105
XJM-93-02X	10	360	0.00036
XJM-93-02X	10 (dup)	649	0.00065
XJM-93-03X	15	3370	0.00337
Geom. Mean:		954	0.00095

Calculation of Kd for Site-Specific Contaminants of Concern

$$Kd = Koc * foc$$

<u>Compound</u>	<u>Koc (mL/g)</u>	<u>foc</u>	<u>Kd (cu m/kg)</u>
Benzene	83	0.00095	7.91E-05
Toluene	300	0.00095	2.86E-04
Ethylbenzene	1100	0.00095	1.05E-03
Carbon Tetrachloride	439	0.00095	4.19E-04

Calculation of Site-Specific Retardation Factors

$$\text{Retardation Factor (R)} = [1 + (p/n)(Kd)]$$

$$\text{where: } p = 2000 \text{ kg/cu meter} \\ n = 0.25$$

<u>Compound</u>	<u>Kd (cu m/kg)</u>	<u>R</u>
Benzene	7.91E-05	1.63
Toluene	2.86E-04	3.29
Ethylbenzene	1.05E-03	9.39
Carbon Tetrachloride	4.19E-04	4.35

No Site/Reference	Contaminant Info	V (m/d)	Results	Notes	Reference
1 Borden, Ontario	BTX stock soln injected into aquifer	0.09	benzene toluene o-xylene m-xylene p-xylene	30 mg/d 37 mg/d 47 mg/d 55 mg/d 33 mg/d	Barker et al. 1987 Barker et al. 1987 Barker et al. 1987 Barker et al. 1987 Barker et al. 1987
2 Rocky Point, NC	residual gasoline from UST	0.08	benzene toluene ethylbenzene o-xylene m,p-xylene	0.0002 1/d 0.0021 1/d 0.0015 1/d 0.0021 1/d 0.0013 1/d	(Borden et al. 1995 (Borden et al. 1995 (Borden et al. 1995 (Borden et al. 1995 (Borden et al. 1995
3 Kalkaska, MI	natural gas condensate	0.2	benzene	Rates from mas balance	Chiang et al. 1989
4 Columbus, MS	stock solutions		benzene p-xylene naphthalene o-DCB	0.007 1/d 0.0107 1/d 0.0064 1/d 0.0046 1/d	MacIntyre et al. 1993 MacIntyre et al. 1993 MacIntyre et al. 1993 MacIntyre et al. 1993
5 Sleeping Bear, MI	residual gasoline from UST release	0.4	benzene toluene ethylbenzene o-xylene m-xylene p-xylene	N.S. 0.02 1/d 0.03 1/d 0.004 1/d 0.004 1/d 0.002 1/d	Wilson et al. 1994b Wilson et al. 1994b Wilson et al. 1994b Wilson et al. 1994b Wilson et al. 1994b Wilson et al. 1994b
6 Sleeping Bear, MI	residual gasoline from UST release	0.4	benzene toluene ethylbenzene o-xylene m-xylene p-xylene	0.07 1/d 0.011 1/d 0.011 1/d 0.014 1/d 0.01 1/d	Schafer, 1994 Schafer, 1994 Schafer, 1994 Schafer, 1994 Schafer, 1994
7 Indian River, FL	gasoline from UST	0.06	benzene	concentration vs. travel time	Kemblowski et al. 1987
8 Morgan Hill, CA	gasoline	0.05	benzene	concentration vs. travel time	Kemblowski et al. 1987
9 Eglin AFB, FL	JP-4 from POL depot	1.3	benzene	averages used here	Wilson et al. 1994a
Eglin AFB, FL			toluene	Rates from conc. vs. travel time	Wilson et al. 1994a
Eglin AFB, FL			ethylbenzene	1,2,4-trimethylbenzene as internal standard	Wilson et al. 1994a
Eglin AFB, FL			o-xylene		Wilson et al. 1994a
Eglin AFB, FL			m-xylene		Wilson et al. 1994a
Eglin AFB, FL			p-xylene		Wilson et al. 1994a

No Site/Reference	Contaminant Info	V (m/d)	Results	Notes	Reference
10 Hill AFB, UT Hill AFB, UT Hill AFB, UT Hill AFB, UT Hill AFB, UT Hill AFB, UT	JP-4 from POL depot	0.5 benzene	toluene ethylbenzene o-xylene m-xylene p-xylene	averages used here Rates from conc. vs. travel time total trimethylbenzene as internal standard	Wiedemeier et al. 1994 Wiedemeier et al. 1994 Wiedemeier et al. 1994 Wiedemeier et al. 1994 Wiedemeier et al. 1994 Wiedemeier et al. 1994
11 Patrick AFB, FL Patrick AFB, FL Patrick AFB, FL Patrick AFB, FL Patrick AFB, FL Patrick AFB, FL	700 gal gasoline	0.13 benzene	toluene ethylbenzene o-xylene m-xylene p-xylene	averages used here Rates from conc. vs travel time using methane as internal standard	Wiedemeier et al. 1994 Wiedemeier et al. 1994 Wiedemeier et al. 1994 Wiedemeier et al. 1994 Wiedemeier et al. 1994 Wiedemeier et al. 1994
12 Fairfax, VA Fairfax, VA Fairfax, VA Fairfax, VA		0.015 benzene	toluene ethylbenzene tot-xylenes	Rates from conc. vs. travel time	Buscheck et al. 1993 Buscheck et al. 1993 Buscheck et al. 1993 Buscheck et al. 1993
13 San Francisco, CA San Francisco, CA San Francisco, CA San Francisco, CA		0.03 benzene	toluene ethylbenzene tot-xylenes	Rates from conc. vs. travel time	Buscheck et al. 1993 Buscheck et al. 1993 Buscheck et al. 1993 Buscheck et al. 1993
14 Alameda Co., CA Alameda Co., CA Alameda Co., CA Alameda Co., CA	gasoline	0.01 benzene	toluene ethylbenzene tot-xylenes	Rates from conc. vs. travel time	Buscheck et al. 1993 Buscheck et al. 1993 Buscheck et al. 1993 Buscheck et al. 1993
15 Elko Co, NV	gasoline	0.04 benzene		Rates from conc. vs. travel time	Buscheck et al. 1993 Buscheck et al. 1993
16 Sampson Co, NC Sampson Co, NC Sampson Co, NC Sampson Co, NC Sampson Co, NC Sampson Co, NC	gasoline from UST	0.04 MTBE benzene toluene ethylbenzene o-xylene m,p-xylene		High NO3 in GW, 1st order rates from mass flux	Borden, 1995 Borden, 1995 Borden, 1995 Borden, 1995 Borden, 1995 Borden, 1995
17 Travers City Travers City Travers City	aviation gas	1.5 benzene toluene tot-xylenes		Rates from conc. vs. travel time	Wilson et al. 1990 Wilson et al. 1990 Wilson et al. 1990
18 Broward Co, FL	gasoline from UST	0.1 BTEX		match w/ Bioplume model	Caldwell et al. 1992

No Site/Reference	Contaminant Info	V (m/d)	Results	Notes	Reference
19 Perth, Australia	gasoline from UST	0.4	naphthalene	0.004 1/d	Thierrin et al. 1993
Perth, Australia			benzene	N.S.	Thierrin et al. 1993
Perth, Australia			toluene	0.006 1/d	Thierrin et al. 1993
Perth, Australia			ethylbenzene	0.003 1/d	Thierrin et al. 1993
Perth, Australia			o-xylene	0.006 1/d	Thierrin et al. 1993
Perth, Australia			m,p-xylene	0.004 1/d	Thierrin et al. 1993
20 Hill AFB	18,000 gal UST	0.14	TPH	Rates from mass balance,	DuPont et al. 1994
Hill AFB			benzene	TPH= 1st order,	DuPont et al. 1994
Hill AFB			ethylbenzene	BTEX-zero order deg	DuPont et al. 1994
Hill AFB			p-xylene	0.06 kg/d	DuPont et al. 1994
21 George AFB, CA			1 benzene	0.0079 1/d	Wilson et al. 1995
George AFB, CA			toluene	0.046 1/d	Wilson et al. 1995
George AFB, CA			ethylbenzene	0.0086 1/d	Wilson et al. 1995
George AFB, CA			o-xylene	0.02 1/d	Wilson et al. 1995
George AFB, CA			m-xylene	0.04 1/d	Wilson et al. 1995
George AFB, CA			p-xylene	0.023 1/d	Wilson et al. 1995

Literature Search Degradation Rate Summaries - Rates include Biodegradation and Dispersion

Compound	Minimum Rate (1/day)	Half-Life (days)	Maximum Rate (1/day)	Half-Life (days)	Average Rate (1/day)	Half-Life (days)
benzene	0.0002	3466	0.045	15	0.0010	663
toluene	0.00045	1540	0.2	3	0.0022	319
ethylbenzene	0.0002	3466	0.0375	18	0.0013	549
o-xylene	0.0009	770	0.21	3	0.0038	181
m,p-xylene	0.0013	533	0.004	173	0.0018	380
m-xylene	0.0016	433	0.04	17	0.0058	120
p-xylene	0.0015	462	0.032	22	0.0047	149

Summary Data from Studies - Rates are Biodegradation Only

Compound	Minimum Rate (1/day)	Half-Life (days)	Maximum Rate (1/day)	Half-Life (days)	Average Rate (1/day)	Half-Life (days)
benzene	0.0008	866	0.045	15	0.0021	327
toluene	0.001	693	0.07	10	0.0036	193
ethylbenzene	0.0002	3466	0.0375	18	0.0010	722
o-xylene	0.004	173	0.21	3	0.0092	76
m-xylene	0.0016	433	0.033	21	0.0050	140
p-xylene	0.0015	462	0.032	22	0.0041	168

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Intrinsic Bioremediation Rate Summary

References

- Barker, J.F., G.C. Patrick, and D. Major. 1987. "Natural Attenuation of Aromatic Hydrocarbons in a Shallow Sand Aquifer." *Water Monitoring Review*, Winter: 64-71.
- Borden, r.C., C. A. Gomez, and M. T. Becker. 1995. "Geochemical Indicators of Intrinsic Bioremediation." Submitted to *Ground Water*.
- Borden, R. C., C.A. Gomez, and M. T. Becker. 1994. "Natural Bioremediation of a Gasoline Spill." In R. E. Hinchee et al. (Eds.), *Hydrocarbon Bioremediation*, pp. 290-295. Lewis Publishers, Boca Raton, FL.
- Buscheck, T. E., K.T. O'Reilly, and S. N. Nelson. 1993. "Evaluation of Intrinsic Bioremediation at Field Sites." In *Proceedings of the 1993 Petroleum Hydrocarbons and Organic Chemical in Ground Water. Prevention, Detection, and Restoration*, pp. 367-381. Water Well Journal Publishing Co., Dublin, OH.
- Caldwell, K. R., D. L. Tarbox, I. D. Barr, S. Fiorenza, L. E. Dunlap, and S. B. Thomas. 1992. "Assessment of Natural Bioremediation as an Alternative to Traditional Active Remediation at Selected Amoco Oil Company Sites, Florida." In *Proceedings of the 1993 Petroleum Hydrocarbons and Organic Chemical in Ground Water. Prevention, Detection, and Restoration*, pp. 367-381. Water Well Journal Publishing Co., Dublin, OH.
- Chiang, C. Y., J. P. Salanitro, E. Y. Chai, J. D. Colthart, and C. L. Klein. 1989. "Aerobic Biodegradation of Benzene, Toluene, and Xylene in a Sandy Aquifer: Data Analysis and Computer Modeling." *Ground Water* 27: 823-834.
- Dupont, R. R., D. L. Sorensen, and M. Kemblowski. 1994. "Evaluation of Intrinsic Bioremediation at an Underground Storage Tank Site in Northern Utah." In *Proceedings of the EPA Symposium on Intrinsic Bioremediation of Groundwater*, pp. 176-177. U.S. Environmental Protection Agency, Washington, D.C.
- Kemblowski, M. W., J. P. Salanitro, G. M. Deeley, and C. C. Stanley. 1987. "Fate and Transport of Residual Hydrocarbon in Groundwater: A Case Study." In *Proceedings of the 1993 Petroleum Hydrocarbons and Organic Chemical in Ground Water. Prevention, Detection, and Restoration*, pp. 367-381. Water Well Journal Publishing Co., Dublin, OH.

- MacIntyre, W. G., M. Boggs, C. P. Antworth, and T. B. Stauffer. 1993. "Degradation Kinetics of Aromatic Organic Solutes Introduced Into a Heterogeneous Aquifer." *Water Resources* 29(12): 4045-51.
- Rafai, H.S., R.C. Borden, J.T. Wilson, and C.H. Ward. 1995. "Intrinsic Bioattenuation for Subsurface Restoration" In Hinchee et al. (Eds), *Intrinsic Bioremediation*. Battelle Press, Columbus OH.
- Schafer, M. 1994. "Methanogenic Biodegradation of Alkylbenzenes in Groundwater from Sleeping Bear Dunes National Lakeshore." M.S. Thesis North Carolina State University, Raleigh, NC.
- Thierrin, J., G. B. Davis, C. Barber, B. M. Patterson, F. Pribac, T. R. Power, and M. Lambert. 1993. "Natural degradation rates of BTEX compounds and naphthalene in a sulfate reducing groundwater environment." *Hydrological Sciences Journal* 38(4): 309-322.
- Wiedemeier, T. H., D. C. Downey, J. T. Wilson, D. H. Dampbell, R. N. Miller and J. E. Hansen. 1994. "Technical Protocol for Implementing the Intrinsic Remediation With Long Term Monitoring Option for Natural Attenuation of Dissolved Phase Fuel Contamination in Ground Water." Air Force Center for Environmental Excellence Publication (draft).
- Wilson, B.H., J. T. Wilson, D. H. Kampbell, B. E. Bledsoe, and J. M. Armstrong. 1990. "Biotransformation of Monoaromatic and Chlorinated Hydrocarbons at an Aviation Gasoline Spill Site." *Geomicrobiology Journal* 8: 225-240.
- Wilson, J.T., F. M. Pheffer, J. W. Weaver, D. H. Kampbell, T. H. Wiedemeier, J. E. Hansen, and R. N. Miller. 1994a. "Intrinsic Bioremediation of JP-4 Jet Fuel." In *Proceedings of the EPA Symposium on Intrinsic Bioremediation of Groundwater*, p. 189. U.S. Environmental Protection Agency, EPA/540/R-94/515.
- Wilson, J.T., J. W. Weaver, and D. H. Dampbell. 1994b. "Intrinsic Bioremediation of TCE in Ground Water at a NPL site in St. Joseph, Michigan." In *Proceedings of the EPA Symposium on Intrinsic Bioremediation of Groundwater*, p. 189. U.S. Environmental Protection Agency, EPA/540/R-94/515.

Carbon tetrachloride

CAS Registry Number: 56-23-5

Half-lives:

• **Soil:** High: 8640 hours (1 year)
Low: 4320 hours (6 months)
Comment: Scientific judgement based upon estimated aqueous aerobic biodegradation half-life.

• **Air:** High: 1.6×10^5 hours (18.3 years)
Low: 1.6×10^4 hours (1.8 years)
Comment: Based upon photooxidation half-life in air.

• **Surface Water:** High: 8640 hours (1 year)
Low: 4032 hours (6 months)
Comment: Scientific judgement based upon estimated aqueous aerobic biodegradation half-life.

• **Ground Water:** High: 8640 hours (1 year)
Low: 168 hours (7 days)
Comment: Scientific judgement based upon estimated aqueous aerobic biodegradation half-life and acclimated anaerobic sediment/aquifer grab sample data (low $t_{1/2}$: Parsons, F et al. (1985)).

Aqueous Biodegradation (unacclimated):

• **Aerobic half-life:** High: 8640 hours (1 year)
Low: 4032 hours (6 months)
Comment: Scientific judgement based upon acclimated aerobic screening test data (Tabak, HH et al. (1981)).

• **Anaerobic half-life:** High: 672 hours (28 days)
Low: 168 hours (7 days)
Comment: Scientific judgement based upon unacclimated anaerobic screening test data (Bouwer, EJ and McCarty, PL (1983)) and acclimated anaerobic sediment/aquifer grab sample data (Parsons, F et al. (1985)).

• **Removal/secondary treatment:** High: 99%
Low:
Comment: Based upon % degraded under anaerobic continuous flow conditions (Bouwer, EJ and McCarty, PL (1983)).

Photolysis:

• **Atmos photol half-life:** High: Not expected to be important
Low:

Comment: Scientific judgement based upon aqueous photolysis data.

IGWMC GROUNDWATER MODELING SOFTWARE

SOLUTE

A Program Package of Analytical Models for Solute Transport in Groundwater

by

Milovan S. Beljin
Hydrolink, Inc., Cincinnati, Ohio
for
Holcomb Research Institute,
Butler University

BAS 15
Version 2.0
July 1989
Released March 1990

INTERNATIONAL GROUND WATER MODELING CENTER

Holcomb Research Institute,
Butler University
4600 Sunset Avenue
Indianapolis, Indiana 46208
USA

TNO-DGV Institute
of Applied Geoscience
P.O. Box 285, 2600 AG Delft
The Netherlands

ONED3

PROGRAM IDENTIFICATION

Program Title: Analytical Model for Solute Transport in a Semi-Infinite Column,
Third-Type Boundary Condition

Program Code Name: ONED3

Programmer: Milovan S. Beljin

Program Organization: International Ground Water Modeling Center
Holcomb Research Institute, Butler University
Indianapolis, Indiana 46208, USA. Tel: 317/283-9458

Date: January 1989

Version: 2.00

Source Language: Microsoft QuickBASIC 4.0

Memory Requirements: 320K

Availability: ONED3 is a nonproprietary code distributed by IGWMC.
A copy of the program on a 5-1/4" or 3-1/2" diskette is available.

Abstract: This program gives the concentration distribution along a
semi-infinite column with the third-type inlet boundary condition.

Comments: ONED3 is based on the van Genuchten and Alves (1982) equation.

ONED3

MATHEMATICAL MODEL

This one-dimensional problem again involves the transport of a nonconservative solute. The governing equation is

$$D \frac{\partial^2 C}{\partial x^2} - \bar{v} \frac{\partial C}{\partial x} - \lambda RC = R \frac{\partial C}{\partial t}, \quad (3.2.1)$$

with all terms having been defined previously.

The initial and boundary conditions for this problem are

$$C(x, 0) = C_i \quad (3.2.2)$$

$$\left(-D \frac{\partial C}{\partial x} + \bar{v} C \right) \Big|_{x=0} = \bar{v} C_0 \exp(-\alpha t) \quad (3.2.3)$$

$$\frac{\partial C}{\partial x}(\infty, t) = 0 \quad (3.2.4)$$

where C_0 is a concentration constant of the injected fluid, and α is the decay constant of the solute at the source.

Van Genuchten and Alves (1982) give the following analytical solutions:

Case 1: $\alpha = \lambda$

$$C(x, t) = (C_i - C_0) A(x, t) + C_0 \exp(-\alpha t) \quad (3.2.5)$$

Case 2: $\alpha \neq \lambda$

$$C(x, t) = C_i A(x, t) + C_0 E(x, t) \quad (3.2.6)$$

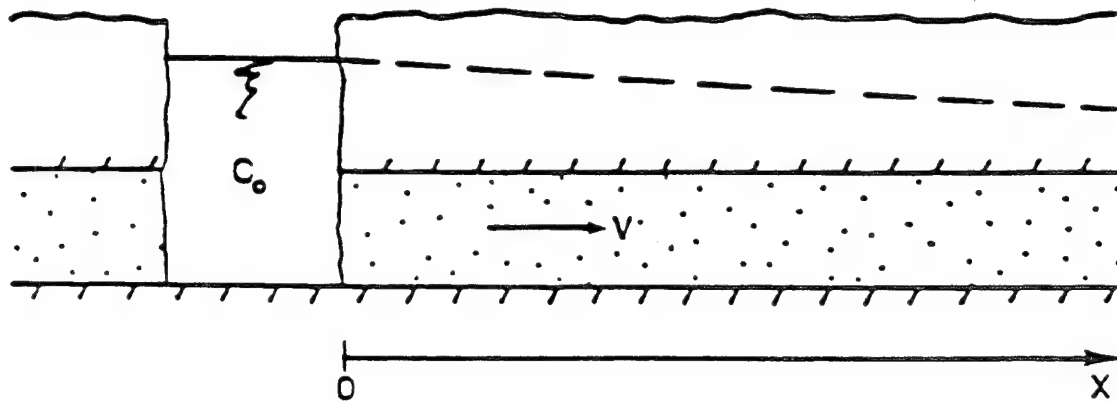
where

$$\begin{aligned}
A(x, t) = & \exp(-\lambda t) \left\{ 1 - \frac{1}{2} \operatorname{erfc} \left[\frac{Rx - \bar{v}t}{2\sqrt{DRt}} \right] \right. \\
& - \left[\frac{\bar{v}^2 t}{\pi DR} \right] \exp \left[-\frac{(Rx - \bar{v}t)^2}{4DRt} \right] + \frac{1}{2} \left[1 + \frac{\bar{v}x}{D} + \frac{\bar{v}^2 t}{DR} \right] \cdot \\
& \left. \exp \left[\frac{\bar{v}x}{D} \right] \operatorname{erfc} \left[\frac{Rx + \bar{v}t}{2\sqrt{DRt}} \right] \right\}
\end{aligned} \tag{3.2.7}$$

$$\begin{aligned}
E(x, t) = & \exp(-\alpha t) \left\{ \left(\frac{\bar{v}}{\bar{v} + w} \right) \exp \left[\frac{(\bar{v} - w)x}{2D} \right] \operatorname{erfc} \left[\frac{Rx - wt}{2\sqrt{DRt}} \right] \right. \\
& + \left(\frac{\bar{v}}{\bar{v} - w} \right) \exp \left[\frac{(\bar{v} + w)x}{2D} \right] \operatorname{erfc} \left[\frac{Rx + wt}{2\sqrt{DRt}} \right] \\
& \left. + \frac{\bar{v}^2}{2DR(\lambda - \alpha)} \exp \left[\frac{\bar{v}x}{D} - \lambda t \right] \operatorname{erfc} \left[\frac{Rx + \bar{v}t}{2\sqrt{DRt}} \right] \right\}
\end{aligned} \tag{3.2.8}$$

and

$$w = \bar{v} \left[1 + \frac{4DR}{\bar{v}^2} (\lambda - \alpha) \right]^{1/2} \tag{3.2.9}$$



Boundary Condition: $\left(-D \frac{\partial C}{\partial x} + \bar{V} C \right) = \bar{V} C_0 \exp(-\alpha t)$

Figure 2. One-dimensional solute transport, third-type boundary condition.

ASSUMPTIONS OF ONED3 MODEL:

- uniformly porous confined aquifer
- the aquifer is homogeneous, isotropic, semi-infinite in the areal extent, and constant in thickness
- a stream (source) fully penetrates the aquifer
- there is one-dimensional steady-state uniform regional groundwater flow from the stream
- the density and viscosity of the solute in the stream and the aquifer are the same
- no solute advection or dispersion occurs through the aquicludes into or out of the aquifer.

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Assumptions:

- 1 one pore volume of water will be extracted at AOC 43J in 6 years
(see water particle tracking results in Quickflow Model)
- 2 effective soil porosity = 0.25
- 3 soil bulk density = 1.98 g/cc $(n = 1 - (BD/PD))$
where n = soil porosity
BD = bulk density, and
PD = particle density = 2.65 g/cc

Calculation of Fraction of Organic Carbon in Soils

<u>Boring</u>	<u>Sample Depth (ft)</u>	<u>TOC (ug/g)</u>	<u>foc</u>
XJM-93-02X	5	1050	0.00105
XJM-93-02X	10	360	0.00036
XJM-93-02X	10 (dup)	649	0.00065
XJM-93-03X	15	3370	0.00337
Geom. Mean:		954	0.00095

Calculation of Kd for Site-Specific Contaminants of Concern

$$K_d = K_{oc} * foc$$

<u>Compound</u>	<u>Koc (mL/g)</u>	<u>foc</u>	<u>Kd (cu m/kg)</u>
Benzene	83	0.00095	7.91E-05
Toluene	300	0.00095	2.86E-04
Ethylbenzene	1100	0.00095	1.05E-03
Carbon Tetrachloride	439	0.00095	4.19E-04

Calculation of Site-Specific Retardation Factors and Solute Transport (Flush) Times

$$\text{Retardation Factor (R)} = [1 + (BD/n)(K_d)]$$

where: BD = soil bulk density = 1.98 g/cc
n = soil porosity = 0.25

<u>Compound</u>	<u>Kd (cu m/kg)</u>	<u>R</u>	<u>Number of Years to Flush to Recovery Wells</u>
Benzene	7.91E-05	1.63	9.8
Toluene	2.86E-04	3.29	19.7
Ethylbenzene	1.05E-03	9.39	56.3
Carbon Tetrachloride	4.19E-04	4.35	26.1

Table E-1
Estimated Soil Treatment Times
Based on Detected Soil Concentrations and 1st Order Degradation
Feasibility Study Report - AOC 43J
Fort Devens

Analyte	K _{oc} (ml/g)	foc (g/g)	K _d (ml/g)	Average Detected Soil Conc. (µg/Kg) [a]	Groundwater Cleanup Criteria (µg/L) [a]	Estimated Soil Conc. to Achieve GW Cleanup (µg/Kg) [b]	1st Order Degradation Const. For GW (1/d)	Estimated Time to Reach Target Conc. (yrs)
benzene	83	0.00095	0.07885	100	5	0.4	0.0015	10.1
toluene	300	0.00095	0.285	3000	500	143	0.0013	6.4
ethylbenzene	1100	0.00095	1.045	7000	500	523	0.0002	35.5
carbon tet	439	0.00095	0.41705	60	5	2	0.0019	4.8

**RESPONSE TO COMMENTS
FEASIBILITY STUDY REPORTS
AREAS OF CONTAMINATION (AOCs) 43G AND 43J**

The following is the Army's response to comments which have been received on the Draft Feasibility Study Reports for AOC 43G and 43J submitted for review on February 9, 1996. Comments addressed in this response package were received from:

U.S. Environmental Protection Agency (USEPA) - Comments dated April 25, 1996; and
Massachusetts Department of Environmental Protection (MADEP) - Comments dated May 10, 1996.

USEPA COMMENTS ON AOC 43G

GENERAL COMMENTS

1. Comment: Establishing a case for intrinsic bioremediation (Table 2-3 and Figure 2-1 were consulted in formulating this comment). The demonstration of the occurrence of intrinsic bioremediation is insubstantial and contains inconsistencies. Table 2-3 shows the expected trend of increasing redox potential, increasing nitrate concentration, and increasing phosphate concentration moving down gradient from the source within the organic plume. However, the lowest sulfate concentration was observed at the down gradient edge of the plume rather than at the center of the plume. Furthermore, chloride concentrations, which should remain fairly constant within the aquifer, are significantly lower in the down gradient plume and down gradient edge. Thus, other phenomena may also be occurring which would then be obscuring some of the alleged biodegradation effects. Please address these inconsistencies in the FS.

Intrinsic bioremediation in the FS is based solely on indirect evidence. A clearer case would be a demonstration of decreasing organic contaminant concentrations over time, coupled with favorable redox and inorganic conditions. Establishing the destruction of the organic contaminants is crucial.

Response: The Army believes that the two "inconsistencies" referenced (sulfate and chloride concentrations in the downgradient zone) are minor exceptions of the general trend shown in Table 2-3 and do not negate evidence that biodegradation is occurring at the site. The results still indicate a noticeable decrease in sulfate concentration in the source area compared with upgradient, perimeter and downgradient plume ($>5 \mu\text{g/L}$ benzene) areas. Under ideal model conditions, one would expect an increase of sulfate in the farthest downgradient wells ($<5 \mu\text{g/L}$ benzene area). However, the apparent decrease in sulfate could be contributed to the smaller data set collected for the downgradient wells (4 sampling points/events each zone) than for the source area and the perimeter area (15 and 8 sampling points/events, respectively). Due to the general variability in the data within many wells between sampling rounds (i.e., AAFES 6 sulfate concentrations jumped from $11,000 \mu\text{g/L}$ in Round 5 to $25,000 \mu\text{g/L}$ in Round 6) a smaller data set is not as likely to be as representative of the true average.

Road salt most likely contributes to the variability of the chlorides as is evident by observing the generally higher concentrations and seasonal fluctuations in wells that are close and downgradient of roadside or parking areas (AAFES-3, AAFES-5, XGM-94-05X, -07X) as compared with more remote wells such as (XGM-94-09X, 10X and AAFES-7). Similar wording will be added to the FS Report.

RESPONSE TO COMMENTS
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(continued)

It should also be noted that water quality parameter concentrations from XGM-94-06X were mistakenly excluded from the downgradient (<5 ppm benzene area) averages in Table 2-3. Average chloride and sulfate concentrations will be corrected in the final FS Report and are slightly higher than those reported in the draft FS Table 2-3 (15,500 $\mu\text{g/L}$ versus 14,000 $\mu\text{g/L}$ for sulfates and 78,625 $\mu\text{g/L}$ versus 35,000 $\mu\text{g/L}$ for chlorides.)

The Army agrees that a clearer case of intrinsic biodegradation would be a demonstration of decreasing organic contaminant concentrations over time. This will be modeled upon collecting additional groundwater data during the predesign phase of the remediation as specified in the FS Report.

2. Comment: **Long-term groundwater monitoring.** To assess the progress of intrinsic bioremediation and to detect any migration of contaminants off-site, annual groundwater monitoring is proposed. This frequency of groundwater monitoring is inadequate to follow the proposed processes and to detect any effects of seasonality which can be very important in the interpretation of results.

Consider the following alternative long-term groundwater monitoring proposal. Monitor groundwater on a quarterly basis for at least 8 quarters and until a statistically significant decrease in contaminant concentrations has been demonstrated (e.g., by the Mann-Whitney test at a 90% confidence level). Then go to annual monitoring until cleanup goals have been achieved for 3 consecutive years.

Response: In the Draft FS, the Army has proposed that additional sampling and modeling be performed as part of the predesign phase (prior to implementing the long-term monitoring plan). Additionally, more groundwater monitoring wells are to be installed. The Army recognizes the importance of collecting a statistically significant data set and will evaluate the need of performing more frequent long-term monitoring (during the initial years) upon reviewing the results of the predesign modeling.

3. Comment: **Hydrogeological Aspects.** Groundwater flow and the interaction between the bedrock and overburden systems remain unclear at this time. This uncertainty affects the evaluation of the groundwater collection alternative.

The groundwater pump tests completed in the overburden and in the bedrock monitoring wells indicated that the flow characteristics and hydraulic properties were different in the two strata. Although hydraulic communication exists between the upper fractured/weathered bedrock zone and the overburden, the groundwater flow in the two systems is governed by different physical properties respective of the geologic strata. Grain size, porosity, and similar properties govern flow in the overburden while fractures and joints control flow in the bedrock. The net effect of these differences may produce variability in flow and contaminant recovery under groundwater pumping conditions. Please state the design criteria for the groundwater collection system. Is the system designed for groundwater collection from the overburden system only? How will collection of contaminants in bedrock groundwater be assured? Is the system designed as a groundwater collection system, groundwater control system, or contaminant recovery system?

**RESPONSE TO COMMENTS
FEASIBILITY STUDY REPORT,
AREAS OF CONTAMINATION (AOCs) 43G AND 43J
(continued)**

Response: Design criteria will be determined following the collection of additional predesign hydrogeologic data, including the installation, sampling, and hydraulic testing of additional bedrock wells.

The groundwater modeling (Appendix A) was performed to estimate the pumping flow rates required to contain the plume at the source area. As described in the Draft FS (pg 4-15), the objective of the groundwater extraction is to intercept the major portion of the plume at the highest concentrations of CPCs, thereby minimizing the potential for migration of CPCs exceeding PRGs. The system would serve mostly as a means of hydraulic containment of the highest concentrations of CPCs in the overburden groundwater. Due to the complex hydrogeology of bedrock, not all contaminants in the bedrock groundwater would be expected to be captured. However, the intrinsic biodegradation component in Alternative 3 and the passive bioremediation component in Alternative 4 would provide treatment of the portion of the plume downgradient of the extraction wells.

SPECIFIC COMMENTS

4. Comment: **Page ES-3, line 17:** Please explain why residential receptors were not considered. (i.e. land reuse is classified as industrial).

Response: Current and future use of the site will be explained. Also the Devens Reuse Plan (Vanassee Hangen Brustlin, 1994) will be referenced. This plan states that the area will be used for Innovation and Technology Business and open space/recreation. This addition is more appropriate on ES-2 where the risk evaluation is first discussed.

5. Comment: **Page 1-10, Section 1.3 Nature and Distribution of Contamination at Areas 2 and 3:** The nature and extent of bedrock groundwater contamination has not been conclusively evaluated down gradient from the source area at the site. The limits of groundwater contamination in wells exclusively screened in bedrock has not been determined. How will the success of a groundwater collection system and or intrinsic bioremediation be evaluated without this data or the presence of adequate monitoring points?

Response: Installation of additional groundwater monitoring wells (to further evaluate bedrock hydrogeology during the predesign phase) is a component of all alternatives evaluated except the No Action Alternative. The success of groundwater collection will be evaluated based upon the results of the predesign data collected (hydrogeological data and modeling) as specified for Alternative 3 and 4 and long-term monitoring. The success of intrinsic bioremediation will be evaluated based upon the results of the predesign groundwater sampling and intrinsic biodegradation modeling as specified for Alternatives 2, 3 and 4.

6. Comment: **Page 1-20, line 30:** Please include the depth to which subsurface is referring to.

Response: A sentence stating this depth is already provided on line 3 of page 1-20 of the draft FS Report.

**RESPONSE TO COMMENTS
FEASIBILITY STUDY REPORT,
AREAS OF CONTAMINATION (AOCs) 43G AND 43J
(continued)**

7. Comment: **Page 1-21 and 22:** Please elaborate for each case on why the receptor evaluated was a future commercial/industrial worker as opposed to residential. Also include a site map which clearly illustrates site boundaries with respect to the reuse/landbank parcel.

Response: Current and future use of the site will be explained. Also the Devens Reuse Plan (Vanasse Hangen Brustlin, 1994) will be referenced. This plan states that the area will be used for Innovation and Technology Business and open space/recreation. A site map which clearly illustrates the Enclave property with respect to the reuse/landbank parcel is already provided in the FS (Figure 4-1).

8. Comment: **Page 1-23, lines 31-33:** The scheduled removal action is expected to remove the contaminated soils associated with the former gasoline USTs. However, the limits of contaminated soil and the nature and extent of bedrock contamination below the former gasoline USTs have not been presented. How will the limits of the excavation be defined and what assurances will be made that all potential source materials will be removed? Please reference 43G Action Memorandum.

Response: This paragraph will be revised in its entirety based upon the results of a meeting held between the regulators and the Army on May 2, 1996 at Fort Devens. The primary discussion at this meeting concerned the residual soil contamination that remains below the existing AAFES gasoline USTs and the possible repercussions on groundwater remediation at AOC 43G. These soils are approximately 20 to 28 feet bgs and would require considerable effort to remove under the COE tank removal action due to soil depth and the proximity to adjacent structures and roadways. Groundwater remediation benefits from removing or in-situ treating this soil are not readily definable at this time. Groundwater sampling results from the RI infer that intrinsic biodegradation is occurring but intrinsic modeling using site-specific degradation rates is not yet possible without collection of data from additional groundwater sampling.

As concluded in this meeting, the Army proposes to remove the three existing gasoline USTs and the sand & gas (S&G) trap and adjacent S&G trap contaminated soils. The Army does not plan to remove the concrete slab on which the existing gasoline USTs rest; the residual contamination within soils 20 to 28 feet bgs that are below the USTs; and any residual contaminated soils adjacent the former waste oil tank excavation. Intrinsic bioremediation data collection and modeling will be performed as part of the design phase to assess intrinsic bioremediation at AOC 43G. However, should modeling and/or long-term groundwater monitoring indicate that the remedial objectives will not be met, the Army will implement further remedial action (i.e., residual soil contamination and/or more aggressive groundwater remedial action). Implementation of the contingency alternative for these two sites will be discussed in the Record of Decision (ROD).

Per request of USEPA, the Army will add an alternative to the final FS that includes residual soil contamination control below the gasoline USTs. (Previously included in the Alternatives Screening Report but removed in the Draft FS because the Army was proposing to remove the soil prior to signing the ROD).

9. Comment: **Figure 1-10: Water Table Elevation Contours:** This figure presents the presumed water table based on water levels taken from monitoring wells regardless of the screened interval and geologic

**RESPONSE TO COMMENTS
FEASIBILITY STUDY REPORT,
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(continued)**

formation being monitored. Although the overburden groundwater system and the shallow bedrock groundwater system appear to be in direct communication, does the comparison of head values in bedrock wells and overburden wells produce a true representation of groundwater flow and contaminant flow paths at the site? What are the presumed vertical flow gradients and conceptual flow components?

Response: Figure 1-10 presents the interpretive water table elevation contours based on data from both overburden and bedrock water table wells. The water table at AOC 43G occurs locally in both overburden and bedrock; therefore, in order to accurately depict potentiometric contours it is necessary to use data from both types of wells. Contaminant distribution indicates that at least some portion of groundwater flow and contaminant transport occurs along the flowlines perpendicular to the interpretive water table elevation contours. Predesign installation of monitoring wells in bedrock will evaluate the potential for vertical flow gradients, and thereby provide more data for the conceptual flow model of the site.

10. Comment: **Table 2-3:** In the list of down gradient wells, the well listed as AAFES-6 should be AAFES-7. Please supply a list of perimeter wells, none are given. As a result, it is unclear what is meant by perimeter.

Response: AAFES 6 will be corrected to AAFES 7. The wells identified in the footnote as downgradient plume wells should be re-identified as perimeter wells. Wells considered to be in the downgradient plume (5 $\mu\text{g/L}$ benzene) in Table 2-3 were XGM-94-08X and -10X and will be added to the footnote.

11. Comment: **Page 4-6, lines 12 through 17:** The modeling of contaminant biodegradation used an average of degradation rates found in a literature search. Since the actual site biodegradation rate is unknown, and might be quite low, the lowest of the literature rates should also be used to establish a reasonable range of conditions (average to slow degradation). Please illustrate this possible condition.

Response: As discussed in Appendix C, model calibration was achieved by varying the half-life and source concentration to obtain a best-fit match with the 1995 groundwater data. Input of the longest half-lives (from the literature search) for individual compounds resulted in very poor matches with the 1995 calibration targets. Inputting a source concentration equivalent to the 1995 source concentration resulted in higher than observed downgradient concentrations; attempts at matching the concentrations at the leading edge of the 1995 plume resulted in modeled source concentrations that were drastically lower than 1995 observed source concentrations.

As part of the predesign phase, the Army will perform additional sampling/analysis to further evaluate the potential for intrinsic biodegradation at the site. The predesign data will be used to further refine the contaminant transport modeling.

12. Comment: **Appendix A. Figure 2:** The groundwater contours produced under pumping conditions indicate the groundwater table will be at or below the bedrock/overburden contact in the area of the pumping wells. It appears the overburden will be dewatered and the wells will be collecting groundwater controlled by the bedrock geology (i.e. fractures, joints, etc.). As indicated in the pump

**RESPONSE TO COMMENTS
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(continued)**

test data and in the slug test analysis of some bedrock wells, there are highly productive bedrock zones and areas that are nonproductive. How will the bedrock/recovery wells be located to assure contaminated groundwater is collected?

Response: Additional hydrogeologic data from pumping tests will be collected as part of the predesign phase to aid in placement and design of the recovery wells. The intent of the groundwater extraction system is to generally provide hydraulic containment of the plume to minimize the potential for migration of the most contaminated portion of the plume (overburden). Intrinsic biodegradation or passive bioremediation would be used for remediation of the downgradient portion of the plume.

RESPONSE TO COMMENTS
FEASIBILITY STUDY REPORT,
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(continued)

MADEP COMMENTS ON AOC 43G

Rebuttals to Army Response to Comments for Alternatives Screening Report, AOC 43G

1. MADEP Rebuttal (General Comment 2).

Comment: An AUL will be required unless all soils at the site are remediated to MCP background levels; a MADEP Grant of Environmental Restriction (GER) would be required to limit groundwater exposures. Also, MCP groundwater standards (e.g., GW-1) would apply to the Site if MCP criteria are more restrictive than MCLs. Even though the Army plans to retain AOC 43G within the Army Enclave, an AUL or similar institutional control would be required to limit exposures until the entire site is remediated to MCP Background levels.

Response: Upon property sale of AOC 43G, the Army will either implement AULs or similar institutional control, or re-evaluate the potential risks assuming a residential exposure scenario. However, as long as the property remains part of the Army Reserve Enclave, there is no unacceptable exposure associated with soil or groundwater on site. Implementation of 5-year site reviews under CERCLA serves to further ensure that the site remedy remains protective of human health and the environment.

Comments on the Draft Feasibility Study Report, AOC 43G

General Comments

1. Comment: The comparative analysis of remedial alternatives cannot be effectively conducted at this time due to limitations inherent within three of the proposed alternatives (Alternatives 2, 3, and 4). These limitations include significant uncertainties with respect to: 1) the effectiveness and time frame of intrinsic bioremediation; and 2) groundwater flow interaction and contaminant fate and transport between the overburden and bedrock. These uncertainties preclude implementation of an objective comparison of the remedial alternatives. For instance, the actual cost to implement Alternative 2 (intrinsic bioremediation and long-term monitoring) could eventually exceed the costs for Alternatives 3 and 4 or another engineered remedial action (e.g., enhanced bioremediation).

Response: The Army believes that the alternative costs are sufficient for comparison purposes. Because the perceived uncertainties impact all the alternatives (i.e., even the more aggressive groundwater containment alternative requires intrinsic biodegradation and is influenced by the bedrock/overburden groundwater flow interaction), alternative costs have been developed using similar conservative assumptions and are believed to be accurate for relative comparisons. Page 5-6 examines some of these uncertainties and presents a brief discussion regarding the sensitivity of the costs.

2. Comment: As noted during the May 2, 1996 meeting at Fort Devens to discuss these sites, MADEP has outstanding concerns on the following:

**RESPONSE TO COMMENTS
FEASIBILITY STUDY REPORT,
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(continued)**

- the adequacy of source control regarding the contaminated soil to be left in place;
- the presence of contamination in the bedrock groundwater;
- the need for further studies regarding on-site intrinsic bioremediation; and
- the need for a contingency plan to be included in the ROD in the event that further studies and monitoring do not demonstrate that groundwater conditions are improving and that further migration is not taking place.

MADEP's acceptance of intrinsic remediation for this site is contingent on the Army's resolution of the above concerns.

Response: These concerns were all discussed and solutions agreed upon during the May 2, 1996 meeting at Fort Devens with the regulators. The primary discussion concerned the residual soil contamination that remains below the existing AAFES gasoline USTs and the possible repercussions on groundwater remediation at AOC 43G. These soils are approximately 20 to 28 feet bgs and would require considerable effort to remove under the COE tank removal action due to soil depth and the proximity to adjacent structures and roadways. Groundwater remediation benefits from removing or in-situ treating this soil are not definable at this time making the effort to remove this soil difficult to justify. Groundwater sampling results from the RI infer that intrinsic biodegradation is occurring but intrinsic modeling using site-specific degradation rates is not yet possible without collection of data from additional sampling rounds.

The solutions discussed and agreed upon were as follows:

- Prior to signing the ROD, the Army will remove the three existing gasoline USTs and the sand & gas (S&G) trap and adjacent S&G trap contaminated soils. The Army will not be removing the concrete slab on which the existing gasoline USTs rest; the residual contamination within soils 20 to 28 feet bgs that are below the USTs; and any residual contaminated soils adjacent the former waste oil tank excavation.
- Data collection (groundwater sampling) and modeling will be performed as part of the predesign phase to assess intrinsic biodegradation at the site. The presence of contamination in the bedrock groundwater and advancement of the overburden plume will be investigated through installation of additional groundwater monitoring wells and by implementing a long-term groundwater monitoring program; and
- Should modeling and/or long-term groundwater monitoring indicate that the remedial objectives will not be met, the Army will implement further remedial action (i.e., residual soil contamination control and/or more aggressive groundwater remedial action). The need for implementing the contingency alternative will be made part of the Record of Decision (ROD).

**RESPONSE TO COMMENTS
FEASIBILITY STUDY REPORT,
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(continued)**

Page-Specific Comments

1. Comment: **Section 1, Page 1-9, Paragraph 2.** Depth to groundwater is reported to range from 12 to 23 feet. Therefore, potential migration of groundwater vapors to indoor should be considered. The risk assessment presented in the RI report (Section 9.3.1) indicates that groundwater vapors are not likely to migrate to indoor air because the depth to groundwater is 15 to 19 feet. This inconsistency needs to be corrected.

Response: The depth to groundwater is incorrectly reported on page 1-9 of the FS Report but accurately depicts this depth on Figures 1-6 to 1-8. The depths will be changed to reflect 15 to 29 bgs as is accurately stated in Section 9.3.1 of the RI.

2. Comment: **Section 1, Page 1-20, Paragraph 2.** Additional discussion needs to be provided pertaining to known and/or potential downgradient human receptors (e.g., possible residential use/development).

Response: The Devens Reuse Plan (Vanasse Hangen Brustlin, 1994) will be referenced in this paragraph. This plan states that the area will be used for open space/recreation and Innovation and Technology Business.

3. Comment: **Section 1, Page 1-23, Paragraph 4.** The document indicates that contaminated soils associated with the former gasoline USTs will be removed. Based on discussions during the May 2, 1996 meeting at Fort Devens, MADEP understood that the Army was proposing to leave potentially contaminated soils in place beneath the concrete slab at the UST area. Additional text should be provided to clarify the extent of the removal actions.

Response: This paragraph will be revised in its entirety due to the changes in the proposed removal action. See the first bullet in the response to General Comment No. 2.

4. Comment: **Section 2, Page 2-2, Paragraph 1.** Reference should be made to the Army's Various Removals project since the Army's intention is to remove contaminant sources and associated contaminated soil. This reference should be included to support the lack of Preliminary Remediation Goals for Soil.

Response: See MADEP Page-Specific Comment No. 3 and the Army's response. There are no PRGs established for subsurface soils because the baseline human health risk assessment did not identify CPCs that present risks greater than USEPA criteria. This is covered on page 2-6 of the draft FS Report.

5. Comment: **Section 2, Page 2-3, Paragraph 4.** The preliminary remediation goals for groundwater should be based on compliance with MCP provisions which can be considered ARARs. The allowable contaminant concentrations specified for soil and groundwater in the MCP should be considered ARARs since they are substantive numerical standards. Other MCP provisions, such as

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implementation of an Activities and Use Limitation (AUL) and/or a Grant of Environmental Restriction (GER) are also ARARs. The FS text and associated tables, should be amended as appropriate to incorporate these and all other MCP ARARs.

Response: The MCP provides that response actions at CERCLA sites shall be deemed adequately regulated for purposes of compliance with the MCP. The Army has chosen not to use MCP Method 1 risk-based standards or Method 3 risk characterization for evaluation of the site. Instead, the Army has conducted a CERCLA risk assessment. Therefore, the Army has not considered the MCP an ARAR.

6. Comment: **Section 2, Page 2-7, Paragraph 1.** See comment to Page 2-2, paragraph 1.

Response: See response to Page-Specific Comment No. 4.

7. Comment: **Section 3, Page 3-6, Paragraph 2.** As requested in MADEP Specific Comment 3 to the Alternatives Screening Report, further details regarding the impracticability of aerobic bioremediation of the entire groundwater plume were added to Section 3.1.4/Page 3-6 of the FS text. However, a table similar to Table 2-9 of the Alternatives Screening Report, was not included in the FS. The requested details regarding limitations of aerobic bioremediation for the entire plume should be tabulated in the FS.

It should be noted that if the proposed intrinsic (anaerobic) bioremediation or the contingent passive (aerobic) biodegradation of the plume do not effectively remediate site groundwater, aerobic biodegradation for the entire plume may be a viable alternative to expensive long-term monitoring.

It is unclear why fouling of the aquifer is cited a concern only for the aerobic bioremediation of the entire plume. Fouling should also be a concern for the "passive" aerobic bioremediation of the downgradient plume, since fouling can result from the introduction of oxygen into the aquifer regardless of the methodology of its introduction.

Response: Page 5 of Table 2-7 in the draft FS (formally Table 2-9 of the Alternative Screening Document) does discuss the same limitations of aerobic bioremediation as discussed on page 3-6.

The Army believes that aerating the entire groundwater plume by injection is impractical due to the limiting characteristics detailed on page 3-6. Fouling is also a concern for passive aerobic bioremediation (p 4-23 discusses anticipated maintenance requirements) but not to the degree of total plume oxygenation. First, there is likely to be less fouling in the passive wells because these wells are placed downgradient of the heavily contaminated area where iron is not as soluble. (Manganese still remains dissolved in the downgradient plume). Secondly, because the passive system generates small amounts of oxygen over an extended period, iron precipitation is minimized. Reportedly, the iron hydroxide has a tendency to deposit on the filter sock which provides a convenient means for capture and cleaning.

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8. Comment: Section 4, Page 4-6, Paragraph 1. The selection of the thirty-year maximum period used to estimate the time frame for intrinsic bioremediation is arbitrary, and does not reflect a reasonable period to base the cost estimate for intrinsic remediation. The first simulation (on/off source) of the ONED8 analytical model for solute transport, in which the contaminant source was removed in 1996 is not readily applicable for this site because: 1) the model does not take into consideration that the bedrock serves as a continuing source of contamination; and 2) the model does not take into account groundwater flow through fractured media. Therefore, presentation of the on/off source simulation and the prediction of achieving groundwater levels below PRGs within four years should not be included in the FS. The second simulation (continuing source), which includes a continuing source of contamination and an infinite time to remediate the site groundwater is more applicable, however, the uncertainties associated with groundwater flow in bedrock remain. A quantitative or semi-quantitative analysis of the intrinsic bioremediation is necessary to substantiate the maximum period. Such an analysis would be based on the results of a biofeasibility study (which is representative of in-situ, intrinsic conditions) and incorporation of site historic analytical data if statistically significant trends are observed over time.

Response: The assumptions and limitations (sources are removed and heterogeneities of the aquifer) of the first model are clearly described on page 3-9 and 4-6. The Army does not believe that these assumptions negate the appropriateness of the model. The first simulation represents the best possible condition and will be retained in the FS Report for comparison with the continuous source simulation (worst condition). Liberally, it can be argued that the source was effectively removed during the UST removals and that the residual soil contamination has little influence on groundwater contamination. Intrinsic bioremediation modeling will be performed, as requested, to substantiate the anticipated cleanup period. Modeling will be performed as part of the predesign phase and will incorporate site historical analytical data if statistically significant trends are observed over time.

9. Comment: Section 4, Page 4-15, Paragraph 2. The groundwater model used for the preliminary design of a groundwater collection system is based on groundwater flow through porous media (e.g., overburden sand and till); however, a significant portion of VOC contamination is reported to be present within the fractured bedrock. The groundwater model used to support the groundwater collection design does not appear to be appropriate, since the model does not account for the uncertainties associated with fractured flow. Therefore, the model is not representative of actual site conditions. The efficiency and implementability of the proposed groundwater collection systems included in Alternatives 3 and 4 cannot be evaluated until additional data are collected or another model is used which more accurately represents the complicated interaction between groundwater flow within the overburden and bedrock.

Response: The purpose of the groundwater collection and treatment system component in Alternatives 3 and 4 is to contain the overburden groundwater plume thereby minimizing the potential for migration of the most contaminated portion of the plume. The purpose of the modeling was to verify that containment of the overburden groundwater is achievable and to estimate, within an order of magnitude, what pumping rates would be required. The model is not intended to examine migration of contaminants within fractured flow to ensure all contamination

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within the bedrock is captured and treated. The intrinsic biodegradation or passive bioremediation components address contamination downgradient of the extraction system. The text will be strengthened to clarify this point. The Army believes that the model is appropriate for Feasibility Study cost purposes. Additional hydrogeological data and groundwater monitoring data are to be collected during the predesign phase to support design (i.e., sizing, placement, and operation of the extraction system) and to verify that the downgradient plume is reflective of intrinsic biodegradation modeling results.

10. Comment: Section 4, Page 4-23, Paragraph 2. The FS refers to use of Passive Bioremediation as a component of Alternative 4. Passive bioremediation is synonymous with intrinsic bioremediation and does not involve human interference or modification of subsurface conditions. The proposed introduction of oxygen and perhaps mineral nutrients into the aquifer to promote biodegradation is an example of active, enhanced, or engineered bioremediation, not passive bioremediation. The FS text and tables should be modified accordingly.

Response: The term "passive" is also a common term to the industry and is used in the FS to identify a treatment level that is between intrinsic biodegradation (modeling and monitoring) and more active bioremediation techniques (injection of nutrients and oxygen or ex-situ treatment). Changing terminology at this time in the review process would only unnecessarily confuse the alternatives being evaluated.

11. Comment: Section 4, Table 4-3. This table of intrinsic bioremediation parameters for long-term monitoring should be amended to include the following: carbon dioxide (metabolic byproduct), number of bacteria (hydrocarbon degraders), number of protozoa, carbon isotopes (organic and inorganic), alkyl benzoates and alkyl phenols (BTEX intermediate metabolites). The carbon isotopes ratios should be evaluated to measure transformation of organic to inorganic carbon (confirmation of intrinsic bioremediation). The ratio of non-degradable to degradable compounds should also be compared to evaluate intrinsic bioremediation effectiveness.

Response: The parameters listed in Table 4-3 are believed to be the basic parameters necessary for evaluating and modeling intrinsic biodegradation. The additional parameters listed by the MADEP can also be helpful in the absence of other indicators but would be best added on a case-by-case basis as needed during the predesign and design phase. Carbon dioxide can be used as an aerobic biodegradation indicator but can be greatly impacted by pH/alkalinity and other geochemical sources and sinks. The BTEX intermediate metabolites are very transitory and their absence does not necessarily infer that biodegradation is not occurring. The ratio of non-degradable to degradable compounds can be beneficial should it become important to assess whether observed contaminant reduction is a result of biodegradation or other natural attenuation processes such as diffusion and dispersion.

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12. Comment: Section 5, Page 5-7, Paragraph 3. Although the comparative analysis of remedial alternatives indicate that Alternative 2 is most cost effective, the actual costs associated with indefinite monitoring of the intrinsic bioremediation may exceed the costs estimated for Alternatives 3 and 4. An increased frequency and expanded list of analytical parameters will be required in order to effectively monitor and evaluate intrinsic bioremediation at the site and add to monitoring costs. Since the thirty-year period for remediation may be optimistic, it may be desirable (less costly) to enhance the intrinsic bioremediation with an engineered remedy to modify subsurface conditions (e.g., addition of nutrients or modification of oxygen levels) to maximize contaminant destruction and minimize the remediation time frame and remedial costs. Alternative 4 of the FS could be modified to include a contingency for more aggressive enhanced or engineered bioremediation of the entire plume.

Response: See response to General Comment No. 1. All alternatives rely on intrinsic biodegradation as a component and are subject to similar inherent uncertainties. The Army maintains that it would be impractical to attempt to aerate and add nutrients to the entire plume due to the site-limiting conditions specified on page 3-6 of the Draft FS Report.

13. Comment: Appendix A. As requested in MADEP's Specific Comment 6 to the Alternatives Screening Report, the Army should provide a detailed explanation, justifying the hydraulic conductivity values utilized as input parameters in the QuickFlow Model. Also, it is unlikely that either the QuickFlow or MODFLOW models can adequately simulate site groundwater flow conditions considering the complexities of bedrock/overburden interaction. Consequently, the value of the model simulations (and hence, groundwater collection alternative analyses) provided are questionable.

Figure 2 needs to be revised such that the elevations of the contours are legible and the identities of the wells used to generate the contour are shown.

Response: The Army's response to the MADEP's Specific Comment 6 to the Alternatives Screening Report was that the hydraulic conductivity would be investigated and the model revised for the FS Report as necessary. The hydraulic conductivity was investigated and changed from 2.02 ft/day in the Alternative Screening Report to 6 ft/day in the Draft FS Report. A detailed explanation of how it was derived and discussion of overburden aquifer thickness is provided on page 2 of Appendix A of the Draft FS Report.

Figure 2 contour elevations will be made more legible. Identifying specific wells would only make the figure less legible. Figure 2 states that contours are based on the May 9, 1995 water level measurements. The reader can readily reference Figure 1-10 for monitoring well identification.

14. Comment: Appendix B, Page 4-1, Paragraph 1. The Biofeasibility Study provided in Appendix B is relevant only for an engineered or enhanced bioremediation for the site. The effectiveness of site intrinsic bioremediation cannot be inferred from the Biofeasibility Study because oxygen and nutrients were added to the study samples. This study is not representative of in-situ conditions relative to intrinsic bioremediation for the site.

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It appears that intrinsic bioremediation is occurring; however, the intrinsic bioremediation assumed by the Army to be occurring at the site is based solely on indirect evidence. Before the intrinsic bioremediation can be properly evaluated, additional data establishing the degree and effectiveness of site intrinsic bioremediation must be provided.

A key factor has not been determined: the rate and effectiveness of the apparent intrinsic biodegradation. While aerobic biodegradation of BTEX compounds has been well documented, there are currently no field data demonstrating significant removal of petroleum hydrocarbons in anaerobic environments. Benzene is particularly resistant to anaerobic biodegradation.

There are many factors which can limit the rate of intrinsic biodegradation. As indicated in Section 4 of the FS, the time frame for remediation is likely between 30 years and infinite. The time frame uncertainty precludes a proper evaluation of intrinsic bioremediation for the site. In order to reduce the uncertainty, the entire subsurface ecosystem must be considered as a whole in order to establish the rate limiting factor affecting intrinsic bioremediation. Without establishing the rate limiting factor, efforts may be wasted by modifying a condition (i.e., oxygen addition) that is not rate limiting. Additional data are required in order to evaluate the rate limiting factors of intrinsic bioremediation.

The general strategy for demonstrating that intrinsic bioremediation is working should include collection of these types of evidence:

- documented loss of contaminants from the site;
- laboratory studies indicating microbes in Site samples have the potential to transform the contaminants under the expected in-situ conditions;
- evidence indicating that the biodegradation potential is actually realized in the field.

Additional information regarding demonstrating the effectiveness of intrinsic bioremediation may be found in the following sources:

- National Research Council on In-Situ Bioremediation Water Science and Technology Board, Commission on Engineering and Technical Systems, National Research Council, 1993. *In-Situ Bioremediation: When Does It Work?* National Research Council, Washington, D.C.
- U.S. EPA, 1993, Guide for Conducting Treatability Studies under CERCLA - Biodegradation Remedy Selection, Interim Guidance, EPA/540/R-93/519a, August 1993.
- U.S. EPA, 1993, Bioremediation Resource Guide, EPA/542-B-98-004, September 1993.
- Baker, C.H. and Henson, D.S., 1994. *Bioremediation*. McGraw-Hill, Inc., New York, NY.

Response: Appendix B is only referenced in the FS Report for discussions pertaining to Passive Bioremediation (Alternative 4) and not intrinsic bioremediation (Alternative 2). The conclusions on

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page 4-1 of the Biofeasibility Study Report simply state that intrinsic biodegradation should continue to be considered as a remedial alternative. This is because the results of the microbial analysis indicated that the unaltered sample contained a healthy population of bacteria.

The Army recognizes that the only observed evidence of intrinsic biodegradation at AOC 43G to date is through indirect measurements (water quality parameters and indicators). As presented in the draft FS Report and during the May 2, 1996 meeting at Fort Devens, the Army proposes to collect additional groundwater data, implement intrinsic biodegradation modeling, install additional groundwater monitoring wells, perform long-term monitoring, and establish a contingency plan to be included in the ROD in the event that modeling/monitoring indicates that groundwater remedial objectives are not being met. The field activities would be performed during predesign and design. Through implementation of these components, the Army intends to provide the necessary evidence that biodegradation potential is actually being realized in the field.

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USEPA COMMENTS ON AOC 43J

GENERAL COMMENTS

1. Comment: Establishing a case for intrinsic bioremediation (Table 2-3 and Figure 2-2 were consulted in formulating this comment). The demonstration of the occurrence of intrinsic bioremediation is weak and contains inconsistencies. The case for intrinsic bioremediation is made based solely on indirect evidence. Table 2-3 shows the expected trend of increasing redox potential moving down-gradient from the source within the organic plume. However, the lowest nitrate, sulfate, and phosphate concentrations were observed at the downgradient edge of the plume rather than at the center of the plume as would be expected. This is inconsistent and requires at least a speculative explanation. Furthermore, chloride concentrations, which should remain fairly constant within the aquifer, are significantly lower in the upgradient well. Thus, other phenomena may also be occurring which would then be obscuring some of the alleged biodegradation effects. This inconsistency should be addressed.

A demonstration of decreasing organic contaminant concentrations over time, which coupled with favorable redox and inorganic conditions, would make a much clearer case for the occurrence of intrinsic bioremediation. Establishing the destruction of the organic contaminants is crucial and is further addressed in the next comment.

Response: Because the "source area" wells may actually be slightly upgradient of the true center of the plume (as noted by the soil concentration contours in Figure 2-3 through 2-8), nitrate, sulfate and phosphate concentrations may decrease farther downgradient as appears to be observed in downgradient wells. Lovely, Chapelle, and Woodward (Lovely, 1994) note that when shallow aquifers are heavily contaminated with organic compounds, it is generally difficult to delineate the distribution of the anoxic redox processes. They further state that reduced products that are actively produced near the source of organic contamination may persist in the groundwater as it moves downgradient into areas where there is little or no ongoing production of these compounds. Therefore observation of reduced nitrate, phosphate and sulfate are not necessarily inconsistent with expected trends and does not negate the evidence that biodegradation is occurring at the site.

Also as part of the Final FS, XJM-93-02X will be regrouped from a source well to a perimeter well. Similar to XJM-93-04X, XJM-93-02X is actually on the fringe of the plume and is may be more representative of upgradient groundwater parameters than plume groundwater. As a result of the regrouping, nitrate within the source area drops from 161 to 58 $\mu\text{g/L}$ which becomes even more consistent with the expected trend. Phosphate concentrations within the source area actually increase slightly as a result of the regrouping of XJM-93-02X (from 687 to 789 $\mu\text{g/L}$). However, a close review of the data reveals unusually large variations in phosphate concentration (increases of up to 2,770 $\mu\text{g/L}$) between 12/94 and 3/95 for wells 2446-2, 2446-3, and 2446-4. These concentrations are not likely to be naturally occurring. Deleting these 3/95 concentrations from the data set brings the average phosphate concentration within the source area down to only 141 $\mu\text{g/L}$ which is also consistent with the expected trend.

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Sulfate concentrations within the source area also increased slightly as a result of the regrouping of XJM-93-02X (from 14,666 to 16,600 $\mu\text{g/L}$). The observed reduction in sulfate in the downgradient area are not necessarily unexpected considering the above discussions (Lovely, 1994). The observed chloride concentrations are not believed to be "significantly" lower in the upgradient well, considering the frequent variations noted often within the same well (i.e., XJM-94-04X: from <2,120 to 15,400 $\mu\text{g/L}$ between 12/94 and 3/95). Application of road salt most likely contributes to the variability of the chlorides.

The Army agrees that intrinsic biodegradation would be more evident by observing a decrease in organic contaminant concentrations over time. Intrinsic biodegradation will be modeled upon collecting additional groundwater data during the predesign phase of the remediation as specified in the FS Report.

2. Comment: Long-term groundwater monitoring. To assess the progress of intrinsic bioremediation and to detect any migration of contaminants off-site, annual groundwater monitoring is proposed. This frequency of groundwater monitoring is inadequate to follow the proposed processes and to detect any effects of seasonality which can be very important in the interpretation of results.

Consider the following alternative long-term groundwater monitoring proposal. Monitor groundwater on a quarterly basis for at least 8 quarters and until a statistically significant decrease in contaminant concentrations has been demonstrated (e.g., by the Mann-Whitney test at a 90% confidence level). Then go to annual monitoring until cleanup goals have been achieved for 3 consecutive years.

Response: In the Draft FS, the Army has proposed that additional sampling and modeling be performed as part of the predesign phase (prior to implementing the long-term monitoring plan). Additionally, more groundwater monitoring wells are to be installed. The Army recognizes the importance of collecting a statistically significant data set and will evaluate the need of performing more frequent long-term monitoring (during the initial years) upon reviewing the results of the predesign modeling.

3. Comment: Hydrogeological Aspects. The characterization of the nature and extent of contaminants in the bedrock remains incomplete. Although one bedrock groundwater sampling point has been monitored (XJM-93-04X), this location is not located directly downgradient from the gasoline UST area. Additional monitoring wells are necessary, screened within the bedrock, to evaluate groundwater contamination in this area.

Response: Installation of additional monitoring wells is a component of every alternative (except No Action) in the Draft FS Report. The text will be clarified to reflect that some of these wells are to be bedrock wells.

4. Comment: The groundwater collection alternative does not specify the design criteria for the system. Is the purpose of the system to collect contaminated groundwater from the overburden only? Please state the design criteria.

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Response: As specified in the Draft FS Report (pg 4-19 and pg 4-29), the purpose of the groundwater collection/treatment component in Alternatives 4 and 5 is to hydraulically contain the plume. Use of the collection/treatment system as the sole means of remediation is impractical due to extremely low hydraulic conductivity in the soils. Based on the RI, only the overburden aquifer is believed to contain contaminants that exceed the PRGs. As a result, the groundwater extraction system specified for Alternatives 4 and 5 would collect groundwater only from the overburden. This will be clarified in the text. Long-term groundwater monitoring will be performed to observe contaminant migration in bedrock and the overburden.

5. Comment: The definition of groundwater flow between the bedrock and overburden systems remain unclear at this time. This uncertainty affects the evaluation of the groundwater collection alternative.

Response: See the response to Comment No. 4. On May 2, 1996 the Army held a meeting with the regulators at Fort Devens to discuss the draft feasibility study (FS) reports for AOC 43G and 43J. AOC 43J discussions pertained to detection of carbon tetrachloride in Round 6 of groundwater sampling at AOC 43J and the possibility of deeper (bedrock) chlorinated solvent groundwater contamination that may be present at the site. Because soils at the site did not present elevated levels of chlorinated solvents, they are not believed to be an issue within bedrock groundwater. Based upon the results of the meeting, installation of bedrock groundwater monitoring wells and long-term groundwater monitoring would be an acceptable solution in response to the above bedrock/overburden groundwater flow uncertainty.

SPECIFIC COMMENTS

6. Comment: **Page ES-2, line 18:** Please change "on" to "off".

Response: "On" will be changed to "off".

7. Comment: **Page ES-2:** please include a paragraph describing why industrial/commercial scenario was used for the downgradient receptor and a site map delineating reuse parcels and Army parcels.

Response: A paragraph will be added describing the planned reuse for downgradient locations. A site map delineating reuse parcels and Army parcels is already included in the draft FS report (Figure 4-1 and 4-2).

8. Comment: **Table 2-3, Notes:** The upgradient well is incorrectly identified as XJM-03-01X. It should be XJM-93-01X. In the list of perimeter wells, the well listed as XJM-94-04X should be XJM-93-04X. Note number 4 is missing. It should read "(4)By Kjeldahl Method."

Response: Table 2-3 will be corrected as noted.

9. Comment: **Page 4-6, lines 18 through 22:** Modeling of contaminant biodegradation used an average of degradation rates found in a literature search. Since the actual site biodegradation rate is unknown, and might be quite low, the lowest of the literature rates should also be used to establish a reasonable range of conditions (average to slow degradation).

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Response: The biodegradation modeling did not specifically use an average degradation rate, but used a rate which resulted in contaminant concentrations that most closely simulated the 1995 observed calibration target concentrations as discussed in Appendix C. As a result, degradation rates actually used in the model are close to the minimum rates found in literature and reported in Appendix C. The Army recognizes the unknown variables associated with the site and the limitations of the model. A more accurate estimate of degradation rates will be obtained as part of the predesign phase when the Army performs additional sampling and intrinsic biodegradation modeling.

10. Comment: Page 4-7, line 18: Objection to the word "verify." The so-called intrinsic bioremediation indicator data cannot verify the occurrence of intrinsic bioremediation, they can only provide additional evidence.

Response: The wording in this sentence will be revised as recommended.

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MADEP COMMENTS ON AOC 43J

Rebuttals to Army Response to Comments for Alternatives Screening Report, AOC 43J

1. Comment: **MADEP Rebuttal (General Comment 3).** The limited temporal trend exhibited for BTEX in groundwater collected from XJM-93-04X is not statistically significant and the vertical characterization of VOCs in groundwater may not be adequate to rule out the need to address contamination in saturated bedrock. Further consideration of bedrock remediation and additional characterization may be required.

Response: On May 2, 1996 the Army held a meeting with the regulators at Fort Devens to discuss the draft feasibility study (FS) reports for AOC 43G and 43J. AOC 43J discussions pertained to the detection of carbon tetrachloride in Round 6 of groundwater sampling at AOC 43J and the possibility of deeper (bedrock) chlorinated solvent groundwater contamination. Because elevated levels of chlorinated solvents were not detected in the soils at the site, they are not believed to be an issue within bedrock groundwater. Based upon the results of the meeting, installation of bedrock groundwater monitoring wells and long-term groundwater monitoring as part of the predesign program for the alternatives were considered acceptable in response to the uncertainty regarding vertical characterization of contaminants.

2. Comment: **MADEP Rebuttal (Specific Comment 7).** The first order degradation rates contain data from sites that may not be representative of AOC 43J. The case study data likely reflect aerobic environments, while the site appears to be an anaerobic environment. Therefore, use of the first order degradation rates should be replaced with data obtained from a site-specific Biofeasibility Study.

Response: Due to the orderly succession of oxidation-reduction reactions, most field occurrences of intrinsic biodegradation involve both aerobic and anaerobic processes. Aerobic processes typically occur on the fringe of the plume where oxygen is an available electron acceptor. While anaerobic degradation is believed to be the predominant process underway at 43J, one cannot exclude the probability that aerobic activity is also occurring at least on the upgradient fringe of the plume. The same applies to the numerous case studies referenced which involve both anaerobic and aerobic processes. These studies represent a range of degradation rates that are appropriate for Feasibility Study purposes. Site-specific degradation rates will be developed from the intrinsic biodegradation modeling to be performed during the predesign phase.

3. Comment: **MADEP Rebuttal (Specific Comment 9).** Alternative 5 would be more effective if in-situ sparging of the groundwater plume was incorporated with the SVE and groundwater collection components. The in-situ air sparging could remove some of the contaminants within the smear zone, and aid in biodegradation by increasing oxygen levels in the source area. This modification should be considered in the FS.

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Response: Because of the high soluble iron and manganese concentrations in groundwater and the low permeable soils, the air sparge wells would likely be fouled within a very short period of time. Therefore, the Army is reluctant to incorporate sparging as a component of Alternative 5.

Comments on the Draft Feasibility Study Report, AOC 43J

General Comments

1. Comment: The comparative analysis of remedial alternatives cannot be effectively completed at this time due to limitations inherent within the four remedial alternatives, other than Alternative 1 (No Action). These limitations include significant uncertainties with respect to: 1) the degree and extent of contamination; 2) adequate monitoring locations to detect migration of contaminants into the Zone 2 of the Sheboken well field; 3) the effectiveness and time frame of intrinsic and "passive" in-situ bioremediation alternatives (lack of Biofeasibility Study); 4) groundwater flow interaction and contaminant fate and transport between the overburden and bedrock; and 5) the effectiveness of the proposed SVE upon contamination within the smear zone (secondary source). These uncertainties preclude implementation of an objective comparison of the remedial alternatives. For instance, the actual cost to implement Alternative 2 (intrinsic bioremediation and long-term monitoring) could eventually exceed the costs for Alternatives 3, 4, 5, or another engineered remedial action.

Response: The Army believes that a comparative analysis can be readily completed at this time. Based on the conclusions of the May 2, 1996 meeting at Fort Devens, the Army was under the perception that many of these "limitations" had been addressed. A discussion and proposed solution based upon the May 2, 1996 meeting follow:

1) Degree and extent of contamination: With the exception of questions regarding vertical gradients, the RI has sufficiently defined the degree and extent of contamination within the overburden. Although the Army continues to believe that bedrock contamination is not an issue, bedrock wells will be installed and incorporated into the long-term monitoring program to monitor for the presence/absence of contamination at deeper gradients. The wells would be installed and monitored during the predesign phase and performed regardless of the alternative selected. A contingency plan will be included in the ROD in the event that modeling/monitoring indicates that groundwater remedial objectives are not being met.

2) Adequate monitoring locations to detect migration of contaminants into the Zone 2 of the Sheboken well field: As discussed in the draft FS Report, all Alternatives entail installation of monitoring wells and long-term monitoring to observe for any migration of contaminants off-site. The exact location of wells is a design issue and impacts all alternatives equally. It does not prevent an effective FS comparative analysis from being performed.

3) Effectiveness and time frame of intrinsic and "passive" in-situ bioremediation alternatives (lack of Biofeasibility Study): Intrinsic bioremediation is a component of every alternative evaluated and impacts the remedial time similarly for each alternative. Even Alternative 5 costs are based on the same intrinsic biodegradation time frame for cost purposes (otherwise Alternative 5 would require

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56 years to remediate by removing contamination by pumping alone). As discussed on p. 5-7 of the draft FS Report, an evaluation of the sensitivity of costs revealed that total costs associated with all alternatives consist primarily of long-term O&M costs and are subject to "across the board" impacts with regard to treatment duration (e.g., this limitation should not impact an effective FS comparative analysis and relative comparison of costs from being performed).

4) Groundwater flow interaction and contaminant fate and transport between the overburden and bedrock: See response to limitation No. 1.

5) Effectiveness of SVE upon contamination within the smear zone (secondary source): This "limitation" was not discussed at the May 2, 1996 meeting. However, the Army believes that there is enough information for FS purposes to evaluate the SVE component of Alternative 5. There is no observed "smear zone" at the site. Soil contaminants are believed to be in equilibrium with the groundwater (page 2-7 of the draft FS Report). Alternatives 4 and 5 create a potential condition where, over time, soil and groundwater will become in disequilibrium. The anticipated effects of this disequilibrium on treatment time are accounted for in Alternative 4 and 5 (pages 4-20 and 4-33 of the draft FS Report). The Army has made simplified, but conservative, assumptions regarding the SVE system for purposes of performing a relative cost comparison of the alternatives. A pilot test is recommended in the draft FS prior to commencing with the actual SVE design.

2. Comment: As noted during the May 2, 1996 meeting at Fort Devens to discuss this site, MADEP has outstanding concerns on the following:

- the presence of contamination in the groundwater which is within the Zone II of the Sheboken wells;
- the need for further studies regarding on-site intrinsic bioremediation; and
- the need for a contingency plan to be included in the ROD in the event that further studies and monitoring do not demonstrate that groundwater conditions are improving and that further migration is not taking place

MADEP's acceptance of intrinsic remediation for this site is contingent on the Army's resolution of the above concerns.

Response: See response to General Comment No. 1.

3. Comment: Since the Army appears to prefer an intrinsic bioremediation (Alternative 2), additional data demonstrating the appropriateness of intrinsic bioremediation will be necessary. These data can only be obtained through additional sampling and analyses and completion of a Biofeasibility Study. Comments pertaining to implementation of a Biofeasibility Study have been provided at the end of this review.

Response: Additional groundwater sampling, installation of groundwater monitoring wells and intrinsic biodegradation modeling will be performed as part of the predesign/design phase.

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4. Comment: Additional consideration should be given to the alternatives evaluated. Alternative 3 of the FS could be modified to include a contingency for more aggressive enhanced or engineered bioremediation. The addition of in-situ air sparging would complement the soil vapor extraction and groundwater extraction to assist in removal of contamination in the smear zone and aid aerobic biodegradation. Another remedy to consider would be in-situ chemical oxidation for the saturated zone.

Response: See response to Alternative Screening Document Rebuttal No. 3.

Page-specific comments

1. Comment: **Section 1, Page 1-20.** The chemical-specific risks are presented in this section (1.4.4). As noted in previous review comments, the document needs to clearly indicate that risk-based decisions will be based on total risks for the environmental medium and on maximum detected concentrations for groundwater exposures.

Response: Page 1-20 describes the baseline assessment that was performed. Discussion of the risk decisions in developing PRGs are covered under in Section 2.0 (2.2).

2. Comment: **Section 1, Page 1-23.** MCP Method 1 GW-2 standards should not be used to evaluate a pathway from the quantitative baseline risk assessment. The purpose of the baseline risk assessment is to evaluate site-specific conditions that may promote or limit migration potential (e.g., depth to groundwater, likelihood of building development, etc.), even if the pathway is not evaluated quantitatively.

Response: The risk assessment was performed following relevant guidance and standards developed by the USEPA and not in accordance with MCP Method 3 procedures. Use of the MCP Method 1 GW-2 standards as a qualitative screening tool is consistent with the Preliminary Risk Evaluation (PRE) approach used to identify those exposure pathways likely to be significant contributors to human health risk. The screening used at AOC 43J showed that vapor migration into building foundations is not expected to pose significant risk at AOC 43J.

3. Comment: **Section 1, Page 1-20, Paragraph 2.** As noted during the May 2, 1996 meeting at Fort Devens, MADEP is concerned about groundwater contamination at this site because it lies within the Zone II (draft Zone II) of the Sheboken well. Additional discussion needs to be provided pertaining to known and/or potential downgradient human receptors (e.g., possible residential use/development).

Response: The Devens Reuse Plan (Vanassee Hangen Brustlin, 1994) will be referenced in this paragraph. This plan indicates that the area immediately downgradient (across Patton Road) will be retained by the federal government for use as the Federal Bureau of Prisons Medical Center. The cemetery, which is comprised of an approximate 450- by 350-foot parcel of land immediately across

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Patton Road will be retained as Army Reserve Enclave property. Therefore drinking water supplies for residential recipients would not be expected within these immediate downgradient areas.

A recent delineation of Zone II aquifer areas by tracing groundwater velocity vectors at Fort Devens shows AOC 43J as being near the edge but within the Zone II aquifer area of the Sheboken Well (Koch, 1995). This delineation is only in draft form at this time and is still under investigation. AOC 43J is located approximately 4,000 feet from the Sheboken Well which is outside the 0.5 mile default radius.

4. Comment: **Section 2, Page 2-2, Paragraph 1.** Preliminary Remediation Goals were not provided for soil, yet Alternative 5 discusses soil treatment with soil vapor extraction to remove secondary sources of contamination to groundwater. It is unclear how the Army plans to address the residual soil contamination under the other alternatives which address soil contamination. A preliminary remediation goal should be proposed for soil. In addition, a preliminary remediation goal for groundwater should include cleanup protective of the Zone II (draft Zone II) of the Sheboken well.

Response: PRGs are not required for soil at AOC 43J because the baseline risk assessment shows that estimated carcinogenic risks did not exceed the USEPA target risk range or the MADEP MCP target risk level. Similarly, estimated noncarcinogenic risks did not exceed the MADEP target level of 1. There are also no observed "secondary sources" at the site. Soil contaminants are believed to be in equilibrium with the groundwater (page 2-7 of the draft FS Report). Alternatives 4 and 5 create a potential condition where, over time, soil and groundwater will become in disequilibrium. SVE (Alternative 5 only) is used to hasten groundwater remediation and is not required to reduce risk. Groundwater PRGs that are protective of residential exposures are not necessary at this time because there is no evidence indicating that contaminants are migrating off the Army Enclave property and there is no exposure to residential receptors. AOC 43J is outside the 0.5 mile default radius of the Sheboken well. Predesign sampling and intrinsic biodegradation modeling in addition to long-term groundwater monitoring will ensure that a contingency plan is readily implemented in the event that contaminants are migrating off the Army Enclave property.

5. Comment: **Section 2, Page 2-3, Paragraph 3.** The preliminary remediation goals for groundwater (and soil) should also be based on compliance with MCP provisions which can be considered ARARs. The allowable contaminant concentrations specified for soil and groundwater in the MCP should be considered ARARs since they are substantive numerical standards. Other MCP provisions, such as implementation of an Activities and Use Limitation (AUL) and/or a Grant of Environmental Restriction (GER) are also ARARs. The FS text and associated tables should be amended as appropriate to incorporate these and all other MCP ARARs.

Response: The MCP provides that response actions at CERCLA sites shall be deemed adequately regulated for purposes of compliance with the MCP. The Army has chosen not to use MCP Method 1 risk-based standards or Method 3 risk characterization for evaluation of the site. Instead, the Army has conducted a CERCLA risk assessment and has not considered the MCP an ARAR.

6. Comment: **Section 3, Page 3-4, Paragraph 2.** The FS refers to use of Passive Bioremediation as a component of Alternative 3. Passive bioremediation is synonymous with intrinsic bioremediation and

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does not involve human interference or modification of subsurface conditions. The proposed introduction of oxygen and perhaps mineral nutrients into the aquifer to promote biodegradation is an example of active, enhanced, or engineered bioremediation. The FS text and tables should be modified accordingly.

Response: The term "passive" is also a common term to the industry and is used in the FS to identify a treatment level that is between intrinsic biodegradation (modeling and monitoring) and more active bioremediation techniques (injection of nutrients and oxygen or ex-situ treatment). Changing terminology at this time in the review process would only unnecessarily confuse the alternatives being evaluated.

7. Comment: **Section 3, Page 3-4, Paragraph 5.** It should be noted that if the proposed intrinsic (anaerobic) bioremediation or the contingent passive (anaerobic) bioremediation of the plume do not effectively remediate site groundwater, aerobic biodegradation for the entire plume may be a viable alternative to expensive long-term monitoring.

It is unclear why fouling of the aquifer is cited a concern only for the aerobic bioremediation of the entire plume. Fouling should also be a concern for the "passive" aerobic bioremediation of the downgradient plume, since fouling can result from the introduction of oxygen into the aquifer regardless of the methodology of its introduction.

Response: See response to Alternative Screening Document Rebuttal No. 3. Fouling is also a concern for passive aerobic bioremediation but not to the degree of total plume oxygenation (p 4-18 of the draft FS Report discusses anticipated maintenance requirements for passive bioremediation). First, there is likely to be less fouling in the passive wells because these wells are placed downgradient of the heavily contaminated area where iron is not as soluble. (Manganese still remains dissolved in the downgradient plume). Secondly, because the passive system generates small amounts of oxygen over an extended period, iron precipitation is minimized. Reportedly, the iron hydroxide has a tendency to deposit on the filter sock which provides a convenient means for capture and cleaning.

8. Comment: **Section 3, Page 3-6, Paragraph 3.** The groundwater model used for the preliminary design of a groundwater collection system is based on groundwater flow through porous media (e.g., overburden sand and till). However, a significant portion of VOC contamination is reported to be present within the fractured bedrock. The groundwater model used to support the groundwater collection design does not appear to be appropriate since the model does not account for the uncertainties associated with fractured flow. Therefore, the model is not representative of actual site conditions. The efficiency and implementability of the proposed groundwater collection systems included in Alternatives 4 and 5 can not be evaluated until additional data are collected or another model is used which more accurately represents the complicated interaction between groundwater flow within the overburden and bedrock.

Response: A significant portion of VOC contamination is not expected to be in bedrock downgradient of the source as inferred by the comment. See response to Alternative Screening Document Rebuttal No. 1.

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9. Comment: **Section 4, Table 4-3.** This table of intrinsic bioremediation parameters for long-term monitoring should be amended to include the following: carbon dioxide (metabolic byproduct), number of bacteria (hydrocarbon degraders), number of protozoa, carbon isotopes (organic and inorganic), alkyl benzoates and alkyl phenols (BTEX intermediate metabolites). The carbon isotopes ratios should be evaluated to measure transformation of organic to inorganic carbon. The ratio of non-degradable to degradable compounds should also be compared to evaluate intrinsic bioremediation effectiveness.

Response: The parameters listed in Table 4-3 are believed to be the basic parameters necessary for evaluating and modeling intrinsic biodegradation. The additional parameters listed by the MADEP can also be helpful in the absence of other indicators but would be best added on a case-by-case basis as needed during the predesign and design phase. Carbon dioxide can be used as an aerobic biodegradation indicator but can be greatly impacted by pH/alkalinity and other geochemical sources and sinks. The BTEX intermediate metabolites are very transitory and their absence does not necessarily infer that biodegradation is not occurring. The ratio of non-degradable to degradable compounds can be beneficial should it become important to assess whether observed contaminant reduction is a result of biodegradation or other natural attenuation processes such as diffusion and dispersion.

10. Comment: **Section 5, Page 5-6, Paragraph 4.** Although the comparative analysis of remedial alternatives indicates that Alternative 2 is most cost effective, the actual costs associated with indefinite monitoring of the intrinsic bioremediation may exceed the costs estimated for Alternatives 3, 4, and 5. An increased frequency and expanded list of analytical parameters will be required in order to effectively monitor and evaluate intrinsic bioremediation at the site. It may be less costly to enhance the intrinsic bioremediation with an engineered remedy to modify subsurface conditions (e.g., addition of nutrients or modification of oxygen levels) to maximize contaminant destruction and minimize the remediation time frame and remedial costs. Alternative 3 of the FS could be modified to include a contingency for more aggressive enhanced or engineered bioremediation. The addition of in-situ air sparging of groundwater to Alternative 5 should also be considered. Air sparging would complement the soil vapor extraction and groundwater extraction to assist in removal of contamination in the smear zone and aid aerobic biodegradation. Another remedy to consider would be in-situ chemical oxidation for the saturated zone.

Response: See response to Alternative Screening Document Rebuttal No. 3. The aggressive aeration/injection technologies are all subject to the site limiting restrictions described on page 3-5 of the draft FS Report.

11. Comment: **Appendix A, Table A-1.** The table should also include partitioning data for carbon tetrachloride and the other chlorinated VOCs present at the site.

Response: Table A-1 is based upon detected soil concentrations. Carbon tetrachloride was not detected in the soil (nor were any other chlorinated solvents detected in soil that exceeded MCLs in groundwater).

12. Comment: **Appendix B, Page B-1, Section 1.** See comment to page 3-6, paragraph 3.

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Response: See response to Page-Specific Comment No. 8 and Alternative Screening Document Rebuttal No. 1.

13. Comment: **Appendix B, Figures 1, 2, & 3.** Much of the text and characters in these figures are illegible. These figures should be presented in a larger format.

Response: The Quickflow model's graphics resolution using converted Autocad drawings as presented in Figures 1, 2, and 3 cannot be improved. All the relevant data for review of the model output (well location, groundwater elevations, and flow) are clearly depicted. The remaining typed text or site features that are lost due to poor resolution are not pertinent to the overall model evaluation.

14. Comment: **Appendix C, Page C-2, Paragraph 4.** The on/off source simulations used in the ONED8 analytical model for solute transport, in which the contaminant source was removed in 1992 is not readily applicable for this site because: 1) the model does not take into consideration that the overburden smear zone and possibly bedrock serve as a continuing source of contamination; and 2) the model does not take into account groundwater flow through fractured media. Therefore, presentation of the on/off source simulation may not be appropriate for inclusion in the FS.

Response: The model is applicable for its intended purpose of simulating existing and potential future concentrations of contaminants of concern in the overburden groundwater to assist in evaluating FS remedial alternatives. There is no observed "smear zone" at the site. Soil contaminants are believed to be in equilibrium with the groundwater (page 2-7 of the draft FS Report). Alternatives 4 and 5 create a potential condition where, over time, soil and groundwater will become in disequilibrium. The anticipated effects of this disequilibrium on treatment time are already accounted for in Alternative 4 and 5 (pages 4-20 and 4-33 of the draft FS Report). Refer to the response to Alternative Screening Document Rebuttal Comment No. 1 regarding groundwater flow through fractured media.

15. Comment: **Intrinsic Bioremediation Case Study (Appendix C, 13 pages in).** It is not clear that the data compiled in this summary table are relevant or appropriate for the site. Since the site groundwater is apparently an anaerobic environment, the case study data, which are likely associated with aerobic sites, may not be representative. The case study data do not include sites with carbon tetrachloride contamination. Also, there are apparently no site data indicating whether the unsaturated overburden is aerobic or anaerobic, therefore comparison with the case study data may not be appropriate. Therefore, presentation of these data may not be appropriate for inclusion in the FS.

Response: See response to Alternative Screening Document Rebuttal No. 2.

16. Comment: **Appendix D, Page D-1, Paragraph 1.** The solute transport model used to calculate 'Flush' times for site VOCs may not be appropriate for the following reasons: 1) the model is based on groundwater flow modeling that may not be representative (see comment to page 3-6, paragraph 3); 2) the model apparently does account for continued releases of VOC via fluctuating groundwater

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contact with the smear zone; and 3) the model apparently does not account for "flushing" of contaminants from the vadose zone via rainwater infiltration. Therefore, the portions of the FS which rely upon this modeling may not be appropriate.

Response: The solute transport model is appropriate for FS purposes. The above issues do not negate the appropriateness of the model for the following reasons: 1) See response to Page-Specific Comment No. 8 regarding the groundwater flow model; 2) There is no "smear zone" as discussed in response to Page-Specific Comment No. 14.; and 3) Minimal flushing from groundwater infiltration is expected because the entire site is paved and source soils within the vadose zone have been removed (page 2-7 of the draft FS Report).

17. Comment: **Appendix E, Table E-1.** Further explanation of this table is required in the text. It is not clear that the data compiled in this summary table is relevant or appropriate for the site. Because there are apparently no site-specific data indicating whether the unsaturated overburden is aerobic or anaerobic, the estimated remediation times predictions based on intrinsic bioremediation are difficult to evaluate. Therefore, the remediation time frames may not be appropriate.

Response: Calculations used first order degradation coefficients from the solute transport evaluation, averaged measured soil concentrations, and theoretical soil concentrations that would exist in soil if groundwater CPCs were at PRGs. These calculations are considered adequate for FS purposes (see response to Alternative Screening Document Rebuttal No. 2.) An explanation of this table is provided on pages 3-16 and 4-20 of the draft FS Report.

18. Comment: **Recommendations for a Biofeasibility Study.** A Biofeasibility Study demonstrating the effectiveness of Site intrinsic bioremediation should be completed to further evaluate the intrinsic bioremediation alternatives included in the FS. The Biofeasibility Study completed for AOC 43G is not sufficient because oxygen and nutrients were added to the study samples. This study is not representative of in-situ conditions relative to intrinsic bioremediation for the site.

It appears that intrinsic bioremediation is occurring at the site. However, the intrinsic bioremediation assumed by the Army to be occurring at the site is based solely on indirect evidence. Before the intrinsic bioremediation can be properly evaluated, additional data establishing the degree and effectiveness of intrinsic bioremediation should be provided.

A key factor has not been determined: the rate and effectiveness of the apparent intrinsic biodegradation. While aerobic biodegradation of BTEX compounds has been well documented, there are currently no field data demonstrating significant removal of petroleum hydrocarbons in anaerobic environments. Benzene is particularly resistant to anaerobic biodegradation and the ability of site microorganisms to degrade chlorinated VOCs (e.g., carbon tetrachloride) has not been evaluated.

There are many factors which can limit the rate of intrinsic biodegradation. As indicated in Section 4 of the FS, the time frame for remediation is likely greater than 56 years. The time frame uncertainty precludes a proper evaluation of intrinsic bioremediation for the Site. In order to reduce the uncertainty, the entire subsurface ecosystem must be considered as a whole in order to establish

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the rate limiting factor affecting intrinsic bioremediation. Without establishing the rate limiting factor, money may be wasted by modifying a condition (i.e. oxygen addition) that is not rate limiting. Additional data are required in order to evaluate the rate limiting factors of intrinsic bioremediation.

The general strategy for demonstrating that intrinsic bioremediation is working should include collection of three types of evidence:

- documented loss of contaminants from the Site;
- laboratory studies indicating microbes in Site samples have the potential to transform the contaminants under the expected in-situ conditions;
- evidence indicating that the biodegradation potential is actually realized in the field.

Additional information regarding demonstrating the effectiveness of intrinsic bioremediation may be found in the following sources:

- National Research Council Committee on In-Situ Bioremediation Water Science and Technology Board, Commission on Engineering and Technical Systems, National Research Council, 1993. *In-Situ Bioremediation: When Does It Work?* National Research Council, Washington, D.C.
- U.S. EPA, 1993, Guide for Conducting Treatability Studies under CERCLA - Biodegradation Remedy Selection, Interim Guidance, EPA/540/R-93/519a, August 1993.
- U.S. EPA, 1993, Bioremediation Resource Guide, EPA/542-B-93-004, September 1993.
- Baker, C.H. and Herson, D.S., 1994. *Bioremediation*. McGraw-Hill, Inc., New York, NY.

Response: The Biofeasibility Study completed for AOC 43G was not intended to be representative of intrinsic bioremediation conditions. It was included in the draft FS Report for AOC 43G to be supportive of the passive (aerobic) bioremediation alternative component as referenced in the draft AOC 43G FS Report (page 3-6).

The Army intends to perform additional groundwater sampling and intrinsic bioremediation modeling as part of the predesign phase to provide evidence indicating that the biodegradation potential is occurring in the field and that remedial objectives are being achieved.

The time frame of 56 years specified in Section 4 of the draft FS report is based upon pumping remediation alone (excluding abiotic removal or biological degradation effects).

REFERENCES

- Koch, Donald, 1995. Transmittal Memo to the Fort Devens Zone II Designation Process Action Team and attached map "Zone II Delineations Based on Manual Tracing of Velocity Vectors 7/28/95"; August 1.
- Lovely, Derek R., F. H. Chapelle, and J. C. Woodward, 1994. "Use of Dissolved H_2 Concentrations to Determine Distribution of Microbially Catalyzed Redox Reactions in Anoxic Groundwater." Environmental Science and Technology; Vol 28, No. 7, July.
- Vanasse Hangen Brustlin, Inc. (1994) "Devens Reuse Plan". Prepared for The Boards of Selectmen - Town of Ayer, Town of Harvard, Town of Lancaster, Town of Shirley, and the Massachusetts Government Land Bank; November 14.